DOCUMENT RESUME

ED 222 762 CE 034 296

TITLE	Airframe Repair Specialist, 2-3. Military Curriculum Materials for Vocational and Technical Education.
INSTITUTION	Chanute AFB Technical Training Center, Ill.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	78
NOTE	634p.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF03/PC26 Plus Postage.
DESCRIPTORS	*Aviation Mechanics; *Aviation Technology; Equipment Evaluation; *Equipment Maintenance; Equipment Utilization; Inspection; Mathematics; Metals; *Metal Working; Military Personnel; Military Training; Personnel Management; Postsecondary Education; Safety; Secondary Education; Supervision; Technical Education; Training; Workbooks
IDENTIFIERS	*Airframe Technicians; Military Curriculum Project

ABSTRACT

These military-developed curriculum materials consist of five volumes of individualized, self-paced training manuals for use by those studying to be airframe repair technicians. Covered in the individual volumes are the following topics: fundamentals of organization and management (ground safety, aircraft ground safety, and aerospace and power equipment safety); fundamentals of metalworking (aircraft metals, corrosion control of metals, metal cutting, hand and machine forming of metals, and shop mathematics); aircraft structural repairs (aircraft fasteners, common attaching methods, structural repairs, and control surface balancing); specialized repairs (transparent enclosures, fiberglass enclosures and parts, metal bonded honeycombs, and aircraft cable and plumbing repairs); and supervision and training (inspections and evaluations, optical alignment, and personnel management). Each volume contains text material as well as workbooks with objectives, exercises, answers to the exercises, and volume review exercises. (MN)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED222762

DEPARTMENT OF EDUCATION
INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)

☑ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

"PERMISSION TO REPRODUCE THIS
MATERIAL HAS BEEN GRANTED BY

L Pfister

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)."

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
The Ohio State University • 1960 Kenny Road • Columbus, Ohio 43210
Tel: (614) 486-3655 Cable: CTVOCEDOSU/Columbus, Ohio

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

AIRFRAME REPAIR SPECIALIST

Table of Contents

Course Description Page 1

Volume I
- Fundamentals of Organization & Management Student Text Page 3
- Fundamentals of Organization & Management Workbook Page 29

Volume II
- Fundamentals of Metalworking - Student Text Page 54
- Fundamentals of Metalworking - Workbook Page 233

Volume III
- Aircraft Structural Repairs - Student Text Page 273
- Aircraft Structural Repairs - Workbook Page 374

Volume IV
- Specialized Repairs - Student Text Page 413
- Specialized Repairs - Workbook Page 508

Volume V
- Supervision and Training - Student Text Page 542
- Supervision - Workbook Page 602

AIRFRAME REPAIR SPECIALIST

Correspondence Course 2-3

1

Developed by:

United States Air Force

Development and Review Dates

April 1975

Occupational Area:

Aviation

Cost:

Print Pages:

622

Availability:
Military Curriculum Project, The Center
for Vocational Education, 1960 Kenny
Rd., Columbus, OH 43210

Suggested Background:

None

Target Audiences:

Grades 10-adult

Organization of Materials:

Student workbooks with objectives, exercises, answers to the exercises, and volume review exercises; text

Type of Instruction:

Individualized, self-paced

Type of Materials:			No. of Pages:	Average Completion Time:
Volume 1	–	*Fundamentals of Organization and Management*	26	Flexible
		Workbook	21	
Volume 2	–	*Fundamentals of Metalworking*	176	Flexible
		Workbook	38	
Volume 3	–	*Aircraft Structural Repairs*	95	Flexible
		Workbook	38	
Volume 4	–	*Specialized Repairs*	91	Flexible
		Workbook	32	
Volume 5	–	*Supervision and Training*	54	Flexible
		Workbook	21	

Supplementary Materials Required:

None

Course Description:

This course is designed as the theory part of on-the-job training to upgrade an Apprentice (semi-skilled) worker to a Specialist (skilled) worker. It contains basic information as well as supervisory training. The duties of an Airframe Repair Specialist are as follows:

- Repairs and modifies aircraft and related sheet metal structures
- Fabricates aircraft and related sheet metal and extruded parts and assemblies
- Repairs and replaces sheet plastic aircraft enclosures
- Repairs aircraft sheet metal tanks
- Fabricates aircraft flexible and nonflexible tubing and electrical conduits
- Fabricates aircraft flexible control cables
- Supervises airframe repair personnel

This course is divided into five volumes of text with accompanying student workbooks. Each volume contains chapters with objectives, readings, and review exercises and answers. Some sections were deleted because they deal with military specific operations, procedures, or forms.

Volume 1 — *Fundamentals of Organization and Management* contains one chapter on ground safety including safety practices, shop safety, aircraft ground safety, and aerospace ground and power equipment safety. The two chapters on communications security and material management were deleted.

Volume 2 — *Fundamentals of Metalworking* contains five chapters covering aircraft metals, corrosion control of metals, metal cutting, hand and machine forming of metals, and shop mathematics.

Volume 3 — *Aircraft Structural Repairs* contains four chapters dealing with aircraft fasteners, common attaching methods, structural repairs, and control surface balancing. The first chapter on technical orders has been deleted.

Volume 4 — *Specialized Repairs* contains four chapters on transparent enclosures, fiberglass enclosures and parts, metal bonded honeycombs, and aircraft cable and plumbing repairs.

Volume 5 — *Supervision and Training* contains three chapters on inspections and evaluations, optical alignment, and personnel management. The chapter on training was deleted because of reference to specific military procedures.

Each chapter has objectives, readings, and review exercises and answers for student self-study and evaluation. This course contains basic information as well as supervisory information, but would best be used in conjunction with a shop or on-the-job learning situation.

53450 01 1171

CDC 53450

AIRFRAME REPAIR SPECIALIST

(AFSC 53450)

Volume 1

Fundamentals of Organization and Management

2-3

Extension Course Institute
Air University

4

PREPARED BY
CHANUTE AIR FORCE BASE, ILLINOIS
AIR TRAINING COMMAND

EXTENSION COURSE INSTITUTE, GUNTER AIR FORCE BASE, ALABAMA 36114

THIS PUBLICATION HAS BEEN REVIEWED AND APPROVED BY COMPETENT PERSONNEL OF THE PREPARING COMMAND IN ACCORDANCE WITH CURRENT DIRECTIVES ON DOCTRINE, POLICY, ESSENTIALITY, PROPRIETY, AND QUALITY.

12

5

Preface

THIS CAREER development course will help you qualify in the upgrade knowledge requirements for airframe repair specialties. This course deals with job-related areas for the airframe repair specialist. It is the self-study portion of your on-the-job training program. It contains the upgrade knowledge requirements for progression from the 3 to 5 skill level of your career field ladder. Even though you have finished the course and passed the 5-skill-level specialty knowledge test, you should not dispose of the volumes of the course.

While this course will help you to prepare for the Specialty Knowledge Tests, you still must satisfy on-the-job proficiency requirements of your unit OJT program before you advance in skill level. Promotion is based on these and other requirements, such as time in grade, performance reports, and promotion quotas. Therefore, you should not expect this course to be an "Aladdin's lamp" that will grant your every wish. Instead, you should expect it to contain the knowledge required for advancement in your career field. You must study to acquire this knowledge.

The first three volumes of this course present knowledge related to airframe repair, fundamentals of metalworking, and structural repairs. The fourth volume is devoted to specialized repairs, including fiberglass and metal bonded honeycomb, and the fifth volume deals with supervisor tasks.

The first volume provides you with information on communication security, airman classification, material management, and ground safety.

The numbers shown on the lower right side of figures are for preparing agency identification only.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC), Chanute AFB IL 61868.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 12 hours (4 points).

Material in this volume is technically accurate, adequate, and current as of August 1971.

6

Contents

Page

Preface iii

Chapter

1 COMMUNICATIONS SECURITY AND AIRMAN CLASSIFICATION 1

2 MATERIAL MANAGEMENT 7

3 GROUND SAFETY 25

Appendixes 45

14

LIST OF CHANGES

COURSE
53450

EFFECTIVE DATE OF SHIPPING LIST
10 Dec 75

CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.

1. CHANGE FOR THE TEXT: VOLUME 1

Page 43, para 9-6, line 1: Change "AFTO Form 35" to "AF Form 2425."

2. CHANGES FOR THE TEXT: VOLUME 3

a. Page 17, para 6-14, line 3: Delete "a salt bath or a hot oil bath is needed" and replace with "still or circulating type or a salt bath is needed." Para 6-15, line 11: Change "2 weeks" to "24 hours." Para 6-16, line 4: Delete the remainder of paragraph beginning with "When 2017-T4 rivets . . ."

b. Page 17, col 2, line 1: Add "(still type)" after "Furnace." Line 5: Change "925° to 950°F" to "930° to 950°F." Between lines 5 and 6, insert the following:

Heating Time - Air Furnace (Circulating Type)

2024-T4	30 minutes	910° to 930°F
2017-T4	30 minutes	930° to 950°F

c. Page 17, col 2, line 8: Change "925° to 950°F" to "930° to 950°F." Para 6-18, line 3: Delete "Earlier, you. . . heat-treating rivets." and replace with "Rivets which have been anodically oxide coated should not be reheat-treated in direct contact with molten salts more than 5 times.

3. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 1

a. Page 3, Chapter Review Exercises, question 3: Change "309" to "3-9."

b. Page 5, Chapter Review Exercises, question 12: Change "descriptiont" to "description." Question 19: Change "Figs 5, 6, 7)" to "(Figs 5, 6, 7)."

c. Page 7, Chapter Review Exercises, question 35: Change "rresponsible" "responsible."

d. Page 9, Chapter Review Exercises, question 17: Change "tthat" to "that."

e. Page 12, Chapter Review Exercises, question 8: Change "AFTO Form 35" to "AF Form 2425." Question 9: Change reference to "9-8." Question 10: Change "AFTO Form 35" to "AF Form 2425."

f. Page 13, Chapter Review Exercises, answer 4: Change to read "SECRET material may be transmitted by selected military personnel and civilian employees, and by registered mail."

g. Page 24, question 17, choice a: Change "nive" to "nine."

LIST OF CHANGES

COURSE NO. 53450	CAREER FIELDS, POLICIES, PROCEDURES AND EQUIPMENT CHANGE. ALSO ERRORS OCCASIONALLY GET INTO PRINT. THE FOLLOWING ITEMS UPDATE AND CORRECT YOUR COURSE MATERIALS. PLEASE MAKE THE INDICATED CHANGES.
EFFECTIVE DATE OF SHIPPING LIST 10 Dec 75	

3. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 1 (Continued)

h. Page 25, question 23, choice c: Change "3 weeks" to "3 weekdays."

i. Page 28, question 50, choice a: Disregard the letter "c" after the word "color."

j. The following questions are no longer scored and need not be answered: 13, 32, 42, 55 and 62.

4. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 2

a. Page 29, question 4, line 3: Change "7xx" to "7xxx." Question 6, line 2: Change "2-24-T3" to "2024-T3."

b. Page 36, question 89, line 3: Change "lead" to "leaf."

c. The following questions are no longer scored and need not be answered: 10, 85 and 97.

5. CHANGE FOR THE VOLUME WORKBOOK: VOLUME 3

Question 17 is no longer scored and need not be answered.

6. CHANGE FOR THE VOLUME WORKBOOK: VOLUME 4

The following questions are no longer scored and need not be answered: 17, 32, 47 and 75.

7. CHANGES FOR THE VOLUME WORKBOOK: VOLUME 5

a. Page 22, question 18: In the stem of the question, change "slight" to "sight."

b. The following questions are no longer scored and need not be answered: 19, 27, 42, and 44.

NOTE: Change the currency date on all volumes to "April 1975."

9

MODIFICATIONS

Chapters 1 and 2 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 3

Ground Safety

ARE YOU safety conscious? The purpose of this chapter is to improve your attitude toward safety precautions that must be observed at all times. Approximately 90 percent of all accidents are caused by unsafe acts of people; thus it is important for us to be on the alert for unsafe acts of personnel. The airframe repair shop personnel work with various types of equipment in all kinds of surroundings. People not in airframe repair are also concerned, since they are in and around aircraft while airframe repairs are being made. Your ground safety officer is responsible for inspecting all work areas, for conducting investigations of all accidents on an Air Force base, and for making reports. He determines causes of accidents and makes suggestions and recommendations for the improvement of safety habits and working conditions. Your watchword must be "Safety Mindedness" at all times.

2. In this chapter you are concerned with the principles of general safety procedures. These principles are applied to on-the-job and off-the-job safety, and their importance to you, your buddies, and the Air Force is particularly stressed. Shop safety is discussed along with the hazards of improper usage of tools and equipment. We must concern ourselves with safety while working in and around all types of aircraft and ground power equipment. Someone could be seriously injured and thousands of dollars worth of material and equipment could be lost as the result of an unsafe act by you or someone else. Think and act safely and you will live longer. If there is an accident you should be able to take action (in the emergency) to save lives and property, and to apply emergency first aid to relieve the suffering of the injured.

6. Safety Practices

6-1. Good housekeeping is achieved by planned and continuous effort to observe principles of cleanliness and orderliness in all activities and operations. In this way, good housekeeping assists in achieving the primary aim of any shop safety program.

6-2. **Disposal of Scraps and Waste.** The accumulation of scraps and waste is minimized if you work efficiently. Be sure that containers are available for scraps or waste as it accumulates. Empty these containers at least once each day, especially at the end of the day. Accumulation, even in proper containers, can be dangerous if allowed to remain for any length of time. A sufficient number of covered metal containers should be placed in the shop where used waste, rags, and other combustible material can be deposited. Use separate metal containers, plainly marked and identified, for discarding oil- and paint-soaked rags, waste, wastepaper, shavings, and similar materials. At the close of each shift, you must see that these containers are either emptied or carried outside the building to a safe place. If allowed to remain inside, these containers create the hazard of spontaneous combustion, which has been the cause of many serious fires.

6-3. **Floor Cleanliness.** Oil pans or drip pans must be used wherever drips or leaks of oil, grease, and similar materials cause hazardous accumulations on equipment or floors. If you see spilled oil on the floor, clean it up immediately. Many people have been seriously injured by slipping on oily surfaces. Use only approved obsorbents to dry up spills of grease, oil, gasoline, and other flammable substances. You should always be sure that floors and walkways are clear of dangerous obstructions. Holes and irregularities in floors should be kept repaired to avert tripping hazards.

6-4. **Fire Prevention.** The observance of prescribed safety practices in the vicinity of flammable gases and vapors is absolutely essential if accidental ignition, explosion, or fire is to be avoided. Using services and operating personnel are responsible for the elimination of fire hazards. You must be on guard against these hazards and eliminate them if you are in position to do so. If not, report them to personnel who are in position to do so.

6-5. Specially designated smoking rooms or smoking areas are provided. Smoking or the striking of matches is not permitted within 50 feet of parked aircraft, hangars, shops, or other buildings in which highly flammable materials are stored or used. If you find it necessary to burn small amounts of rubbish in containers, the burning must be done in a suitable container. It must be located at least 50 feet away from the nearest building in an area free from dry grass, combustible debris, or flammable material. The container should also be provided with a covering screen to prevent the escape of sparks and embers.

6-6. *Various types of fire extinguishers.* Some of the various types of fire extinguishers used on the different types of fires are listed below:

a. Water extinguishers cool and blanket the fire. In the case of liquids that readily mix with water, such as ethyl alcohol, water extinguishes through dilution. It is effective on oil fires only when applied as a very fine spray or heavy mist over the entire surface. It may also be applied in large volumes, such as through the use of a fire hose or deluge sprinkler on a relatively small amount of burning fuel or oil.

b. Chlorobromomethane (CBM), also referred to as CB, is used by the Air Force in aircraft fire extinguishing systems. It is particularly effective against electrical fires. CBM is less toxic than carbon tetrachloride, but the same safety precautions are required concerning the handling of it. Turn off the electricity and open all windows and doors. Inhalation of the highly toxic fumes is dangerous to personnel.

c. Foam cuts off air through blanketing and also has some cooling value. The foam should be applied in such a manner as to cover the entire surface of the burning material. Sometimes vapors may be given off from the burning substance and pass through the foam. Foam is broken down by certain solvents (alcohol, acetone, and ether) and is ineffective on such substances. Foam is a recommended extinguisher for use on flammable liquids such as oil and grease.

d. Carbon tetrachloride (commonly known as pyrene) extinguishes by blanketing the fire with a heavy vapor that will not support combustion. The liquid has a high electrical resistance; hence, its chief value is for fires in electrical equipment. The fumes are toxic; therefore, when this extinguisher is used in closed places, special precautions must be exercised to avoid inhaling the fumes.

e. Carbon dioxide is an inert gas approximately 50 percent heavier than air. It extinguishes chiefly by blanketing. It also exerts some cooling effect because of the low temperature of the steam. It is discharged from the cylinder in which it is held in a liquid form. It builds up pressures of 800 to 900 pounds per square inch (psi) in the container. It is recommended for extinguishing fires in electrical equipment but can also be used to extinguish chemical fires such as oil, fuel, paint thinner, and grease.

6-7. *Explosimeter.* The explosimeter is an instrument used to detect and indicate the presence and intensity of combustible gases. Before this instrument is used for the detection of combustible gas concentrations, it must be turned on and purged of any existing vapors from the previous test. This is done by squeezing the attached aspirator bulb until the sampling tube and instrument are cleared. The sampling tube is then placed in the area to be tested, and the aspirator bulb is again squeezed. The highest resultant reading on the indicator shows the maximum explosive hazard in the area tested. If the explosive hazard is above the allowable safe limits, the area must be completely ventilated until it is clear and safe working conditions exist.

6-8. The primary maintenance of instruments that use dry-cell batteries and filaments consists of replacing parts as necessary. Calibration and repair of the indicator must be accomplished by a qualified instrument specialist (PME laboratory technician). This is done on a regular schedule.

6-9. **Handling Materials.** Material handling includes lifting, loading, storing, or other movement of supplies and equipment in any form. This is done either by hand or mechanical means. The improper handling of materials is one of the chief sources of injury to personnel. Back strains, crushed toes, lacerations, and other injuries commonly result from poor handling practices. Prescribed preventive measures should be taken to insure that material handling accidents are kept to a minimum.

6-10. *Wearing personal protective equipment.* Wear personal protective equipment, such as leather gloves and safety-toe shoes, when required. You must always observe safety practices prescribed in the manual on the handling of all loads. The proper lifting, carrying, and depositing of loads should always be practiced. The normal maximum load which you should lift is 50 pounds. Before lifting an object, be sure that the grasping surface is free of oil, grease, or other substances which may cause the hands to slip. Your footing should be firm, in case the center of gravity of the object should shift while you are holding it. You should lift the object with the body in a squatting position with the back straight and the legs exerting most of the lifting force. The lift can then be made smoothly and evenly without undue strain.

6-11. *Carrying loads.* Carry the load as close to the body as possible without the necessity of shifting the grip. You must insure that your view in the direction you are carrying the object is clear and unobstructed. Be sure there are no slippery substances or tripping hazards on the floor in your path.

6-12. *Depositing loads.* You should use the same procedure for depositing the load, except that the sequence will be reversed. Lower the load by bending the legs and squatting with the back straight so that balance is maintained. Exercise care in releasing the load, to prevent injury to the fingers, hands, or toes.

6-13. **Using Handtools.** The misuse of handtools causes many accidents because the average person thinks that these are simple devices. They are simple devices, but they can be very dangerous if not used properly. Some of the following tools that you use as an airframe repairman or technician can cause you many hours of pain if misused.

6-14. *Hammers.* The hammer is the most commonly used handtool and is involved in about one out of every five handtool injuries. You use the ball-peen, tinner's, and cellulose type hammers frequently. When doing any type of work with the hammer, always use the proper hammer for the job at hand. The ends of hammer handles should never be used for pounding or tapping because this practice damages and weakens the handle. When striking an object with a hammer, make certain the hammer face is parallel to the face of the object being struck. Use soft, nonferrous hammers for striking casehardened or tempered tools and surfaces; never use hammers which show defects, such as cracks in the face or head. Flying particles can injure your eyes.

6-15. *Screwdrivers.* Screwdrivers present an accident hazard because many people don't know how to use them properly. The screwdriver is designed for one principal purpose—to loosen and tighten screws. When it is used for other purposes—which it often is—it may cause a variety of accidents. Always use a screwdriver of the proper size for the job. Make certain that the size of the blade matches the screw slot. Do not hold work in one hand and the screwdriver in the other. Use a vise or a suitable rest to secure the work. Never use a screwdriver as a substitute for a nail puller, punch, or chisel, because these practices will bend the shank, mar the blade, or splinter the handle.

6-16. *Files.* All files present hazards because of their brittleness, abrasive surfaces, and tanged handles; therefore, you should practice safety in the use of files at all times. A file without a handle should never be used, since the tang may be forced into your hand if an obstruction is met. Select a handle of the proper size for the tang, and tap on securely before use. The part filed must be clamped in a vise or otherwise made secure, and its surface must be adequately protected against marring by some soft material between the material being worked and the vise jaws. A file must never be used for prying. The tang end is soft and bends easily. The body of the file is very brittle and will snap under strain or stress. Hammering on a file is dangerous because the file may splinter and scatter sharp fragments that are dangerous to you and others. They can put out an eye.

6-17. *Punches and cold chisels.* Punches, chisels, and other tools which must be held by hand and struck should be kept free of oil, grease, and other slippery substances. When striking these tools, hold them near the top to minimize the danger of striking the hand solidly. A rubber guard may be fitted on the punch or chisel above the hand to guard against striking your hand. Wear goggles or a face shield at all times when using a punch or chisel on metal or other brittle material to protect your eyes. The heads of striking tools should always be kept shaped. Mushroomed heads are very dangerous, since flying bits of metal may strike either you or someone nearby.

6-18. *Other handtools.* There are many other handtools which have not been covered here. You should always give careful consideration to safety before using any handtool. A little forethought may save many dollars in time lost and materials wasted as well as painful injury to you and others.

6-19. **Using Portable Power Tools.** The portable power tool is supplied with power from an external source which permits increased mobility. Portable power tools may be operated by electricity or air pressure, or by means of a rotating flexible shafting. Hazards connected with the use of portable power tools are electrical shock, burns, cuts, bruises, strains, particles in the eyes, and explosions.

6-20. *Electrical Tools.* These tools are used in many operations. Because of the source of power, electrical hazards are present. Many of these, in addition to hazards associated with the tool itself, can be eliminated. Unless electric power tools are of an approved explosion-proof design, they should never be used in an area where flammable liquids or gases are present, used, or stored. You should always see that exposed metal parts are grounded properly. Grounding is very important when electrical power tools are used in wet or damp locations. Electrical cords on power tools must not be subjected to such abuses as scraping, contact with oil and grease, kinking, flexing, crushing, and excessive tension. Always inspect the cord before using it. If the cord is defective, get it replaced at once. Electric extension cords must be properly connected and secured to prevent a spark due to accidental disconnection. Use the overhand tie to more properly secure the connection of extension cords when in use. Remove these extension cords and store them where they will not be subjected to abuse.

6-21. *Compressed air operated tools.* Compressed air operated tools are safe to use around aircraft and where there is a possibility of fire hazards due to flammable liquids and gases. Use good-quality hose and be certain that all hose connections are secure. The air valve should always be operated and controlled by hand. If you are using pneumatic hammers, do not point them at anyone, since the rivet set may be thrown out and could cause injury to someone or something. If you must change rivet sets or other tools, always shut off the air or disconnect the hose from the hammer. Many people do not realize the dangers of horseplaying with compressed air. Do not use air for any other purpose than that for which it is intended. The practice of blowing dust or dirt off your clothing or the clothing of others must not be allowed.

6-22. **Using Power Machines.** All power machines are classed as being very dangerous if you do not take proper precautions. Some of these tools are very simple, whereas others are highly complex. Some of the complex types trigger a sequence or procedure of steps which they must follow after having been activated. If you neglect to take proper care before the machine is put into operation, you will not be able to stop the chain of events. You might injure yourself or someone working with you. For this reason always be sure of your machine and of yourself before beginning a job. Take all these necessary precautions.

6-23. *The bandsaw.* This machine does not seem very dangerous. In relation to others you use, it isn't as likely to cause serious damage; yet it still has a moving saw blade that can cut a finger off. When working with a bandsaw be sure that the blade is sharp, the machine is operating smoothly, and oil and chips are not on the floor in your work area. Be certain to watch the work you are sawing, and see that there is no horseplay around the machine while it is in operation.

6-24. *Power shear.* As an airframe repairman, you have many opportunities to use the power shear. This machine is to be operated by two men. Extra precautions must be taken with this machine because it has a cutting capacity that will sever a hand or arm without so much as slowing the movement of the blade. Primarily, you should see that your hand or the hand of someone working with you is not in the path of the blade. You should also check the adjustments of your machine before cutting material. Check that no scrap material or oil has been left around the machine.

6-25. *Power brake.* The power brake can be used to make many varied shapes and forms. Safety precautions for this machine are similar to those of the power shear—that is, watch where your hands and your helper's hands are before starting any operations. Also, do not try to bend any material which is thicker or harder than is recommended for this particular machine.

6-26. *General precautions.* You use many other power tools as an airframe repairman or technician. All of these tools have specific safety precautions which you should observe. Safety rules for many of these machines are similar. Note some of the most important of these rules.

6-27. Be certain that all safety guards are installed and are in good repair before you operate a machine. When guards are removed for maintenance, oiling, inspection, or repair, see that they are replaced before the machine is operated. Only qualified operators should use power equipment without proper and direct supervision. Never allow power equipment to run unattended. If you have to talk with someone or leave the machine for any reason, turn it off. Turn off the machine before attempting to adjust or reset any part with which you are working.

6-28. **Using the Safety Manual.** You run into many situations during your normal work when you need specific safety instructions or governing regulations. AFM 127-101, *Industrial Safety Accident Prevention Handbook*, has been developed from all available sources of information pertinent to safety in all Air Force ground operations. Included are actual accident reports and records compiled for the Office of Ground Safety. This manual includes safety precautions applicable to every phase of your military activity, both on the job and off the job.

6-29. Among the various subjects covered in the *Industrial Safety Accident Prevention Handbook* are: accident prevention fundamentals, USAF ground accident, personnel safety, accident prevention, standard definitions and interpretations, safety regulations and standards, equipment and facilities standards, motor vehicle operation, hazardous substances, and personnel protective equipment and detection devices. As you see, almost every type safety problem is covered; so when in doubt, always check this manual. Which ones apply to you?

6-30. **Off-the-Job Safety Precautions.** Do you expect to be on the job tomorrow? You have some time off—you may plan to go hunting, fishing, hiking, or swimming. Do not throw caution to the wind. You are not free from hazards, both natural and manmade. Just because you are on leave, danger doesn't take a holiday.

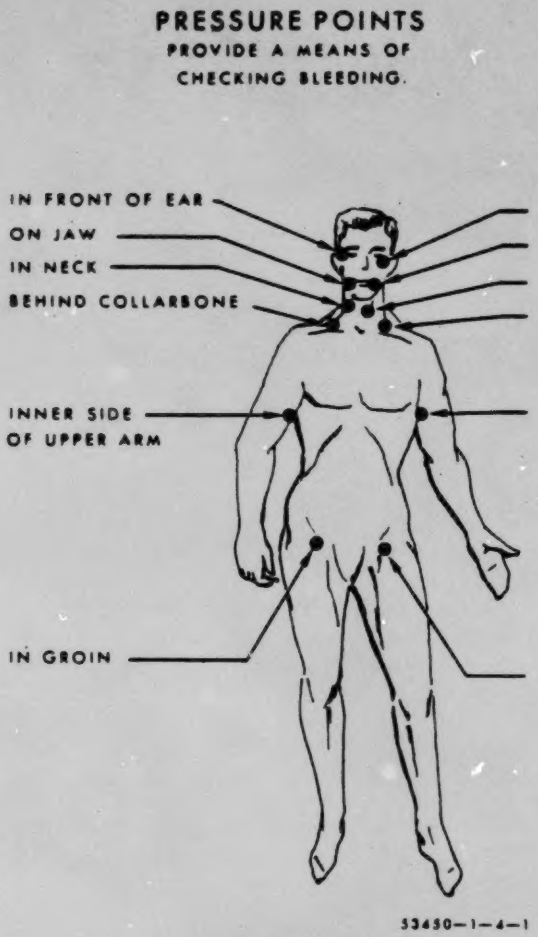


Figure 11. Pressure points.

6-31. Some of the off-duty and on-duty hazards are listed below:

a. Wounds, minor or severe.
b. Fractures, simple or compound.
c. Burns, minor or severe.
d. Drowning.
e. Electric shock.
f. Poisoning.
g. Sprains.
h. Poisonous plants.
i. Animal bites.
j. Insect bites.
k. Heat stroke and frost bite.

6-32. **First Aid.** First aid is defined as the immediate and temporary care given the victim of an accident. It also applies to a person taken suddenly ill and who is given attention to relieve suffering until medical aid is obtained. First aid is more than applying a dressing or a splint. It relates to the victim's mind and spirit as well as his physical injuries or illness. He is encouraged if he feels he is in competent hands. The good first aider deals with the whole situation, the person, and the injury. Know what to do and do only what is necessary. Call for medical assistance as soon as possible.

6-33. **Wounds.** Wounds are caused by contact with sharp objects such as metal corners and edges. Any number of machines used in the airframe repair shop can cause wounds of a minor or severe nature.

6-34. *Abrasions made by rubbing or scraping.* Floor burns or scuff burns, although called burns, are true wounds. First aid for such a wound includes the following steps:

(1) Wash your hand with clean water and soap.

(2) Cleanse the injury thoroughly with boiled water (cooled to room temperature) and soap. A stream of clean, running tap water is also used if the former is not available.

(3) Apply a dry sterile or clean dressing, and bandage it securely in place.

(4) Tell the patient to see his doctor immediately if any signs of infection appear.

6-35. *Incised wounds, sharp cuts that tend to bleed freely.* The primary objective for the first aider is to stop the bleeding as soon as possible. This is done in one or more of the following steps:

(1) Apply direct pressure over the wound with a clean cloth. Application of pressure with the bare hand may be necessary to stop major blood loss.

(2) Add additional layers of cloth to form a good-sized covering.

(3) Bandage firmly into place.

(4) Take the patient to the doctor or hospital.

(5) Blood loss from a severed artery can be slowed down by pressure applied at pressure points. See figure 11 for these.

(6) A tourniquet can be used when the choice is between the chance for loss of life or limb (see fig. 12).

6-36. *Lacerated, jagged, or irregular wounds often associated with much tissue damage.* First aid for this type of wound is to stop the bleeding as soon as possible. Follow these steps:

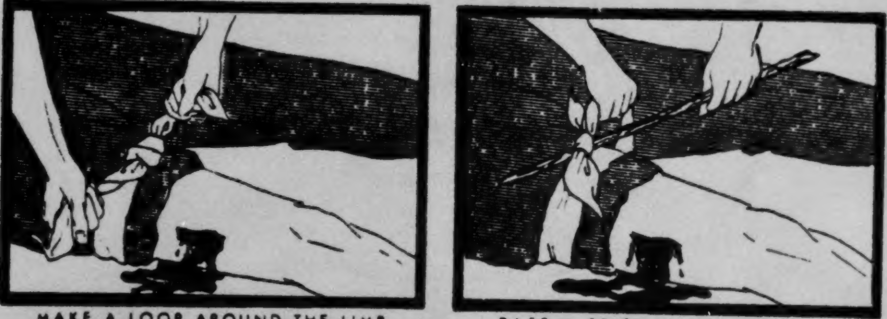
(1) Apply pressure over the wound with a clean cloth and add compress.

(2) Bandage compress securely.

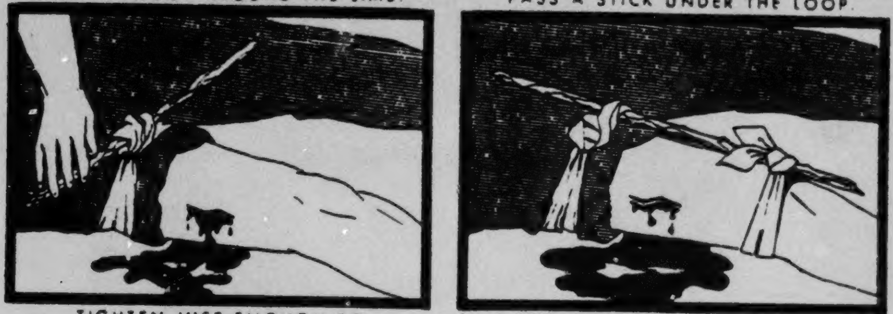
(3) Treat for shock.

(4) Secure medical aid as soon as possible.

6-37. *Puncture wounds.* A sharp object such as a punch, screwdriver, or tool may penetrate the skin. This type of wound often does not bleed



MAKE A LOOP AROUND THE LIMB.
PASS A STICK UNDER THE LOOP.



TIGHTEN JUST ENOUGH TO STOP BLEEDING.
SECURE TOURNIQUET IN PLACE.
53450-1-4-2

Figure 12. The tourniquet.

freely but becomes infected. First aid for this type of wound is primarily to be sure it is properly cleaned. The following steps should be used:

(1) Wash your hands with clean water and soap.

(2) Cleanse the wound and the area around it thoroughly.

(3) Use sterile gauze and apply a 2-percent iodine solution to the wound and the area around it.

(4) After the antiseptic is dry, cover the wound with sterile gauze. Tape the bandage securely in place.

(5) A tetanus shot should be given if the wound is deep. No one wishes to die of lockjaw.

(6) Watch carefully for signs of infection. If it occurs, see your doctor at once.

6-38. **Fractures.** A person with a fracture must be handled carefully to prevent making the injury worse. Shock can easily be the result accompanying a severe fracture. In an emergency, there may not be time to check for broken bones; the victim might have to be moved first. After the individual is in a safe location, move him as little as possible. A fracture may be suspected if:

(1) There is an inability to move a part of the body.

(2) The part has an abnormal shape.

(3) There is pain on movement with extreme tenderness over the injury.

(4) There is swelling and change of color of the damaged area.

First aid for a fracture is as follows:

(1) Treat the victim for shock.

(2) Immobilize the injured member by the use of splints or other means.

(3) Secure medical aid at once.

(4) If a wound accompanies the fracture, stop the bleeding.

6-39. **Burns, Minor or Severe.** Burns may be caused by high temperatures or cryogenic (extremely cold temperatures. First aid measures are the same for both. Treat the patient for shock and obtain medical assistance. Do not touch the burn or try to remove pieces of fabric which stick to the burned area. The patient may be given plenty of nonalcoholic liquids provided there is no evidence of internal injury. Cases in which injuries are minor and which are not classified as emergencies may be treated at more convenient times. All injuries, no matter how minor, should receive medical attention.

6-40. For acid burns or corrosive and cryogenic splashes, put the victim under an emergency shower, remove any clothing saturated with the harmful liquid, wash off the liquid with large amounts of water, and secure medical attention.

6-41. **Drowning.** Many people die from drowning each year. You may be an expert swimmer, but don't take chances such as diving into water you are not familiar with. Submerged rocks, roots, etc., should be located; also, water depth should be known before you dive in. Swimming alone should be avoided, and a swimmer should know how to safely rescue another person before he attempts to do so. First aid for a drowning victim includes getting him out of the water. Apply artificial respiration, keep him warm, and secure medical aid if possible.

6-42. **Electric Shock.** When you are working around and with electrical equipment, be careful. Using electrical equipment that is not in good repair or properly grounded is hazardous. First aid for an electrical shock victim is to cut off the power source or get him away from it. In attempting to get a person loose from the charged object, don't endanger yourself. Use some article of clothing or other nonconductor to pull or push him away. Apply artificial respiration if he is not breathing. Secure medical aid as soon as possible.

6-43. **Poisoning.** There are many sources of poisoning, such as liquids and gases, some of which are quite toxic. Since you are working in the airframe repair shop, we will deal primarily with gases and vapors that may be present in your shop. Carbon monoxide gas or vapors are often fatal if proper precautions are not taken. The shop is ventilated either by natural means or exhaust fans where these gases or vapors may exist. Symptoms are drowsiness, headache, and listlessness; a sense of well-being and buoyance, excitement, and disorientation; in a later stage, a reduced level of consciousness, convulsions, and finally coma. First aid for a person developing any of these symptoms consists of getting him into fresh air, which will usually revive him. If clothing is saturated, remove it at once and place the victim in a deluge shower.

6-44. If a victim is found unconscious, move him into fresh air and give him oxygen if available. Keep him warm with blankets, coats, etc. Give him artificial respiration if he is not breathing. Get medical help as soon as possible.

6-45. **Sprains.** Sprains are the result of overloading some of our muscles. This causes muscle tissue damage and tendon damage as well. When you are tired, in a hurry, or excited, you do not use your body muscles properly. A strain can be a sprain which is often more lasting in effect than a break. Guard against sprains by being careful and acting sensibly. First aid for a sprain is to place a pillow under the affected member and apply cold wet applications or an ice bag for the first half-hour to retard the swelling. Keep the affected joint quiet; do not walk on a sprained ankle until it has a protective support; have the sprain X-rayed; chipped fractures often accompany a sprain.

6-46. Dislocations are the more serious types of sprains. The ligaments at the joints are stretched and often damaged. Only a qualified medical person should treat dislocations. Dislocations, however, should be put back in place promptly and bandaged.

6-47. **Poison Plants.** Three of the poisonous plants found in the United States are the common poison ivy, Western poison oak, and the poisonous sumac. Some people are immune to these plants, but others are not. Serious discomfort is the result of contact with these plants. Learn to recognize and avoid them if possible. The best first aid for a rash caused by contact with poisonous plants is to first wash the affected skin with a good soap and water; avoid scratching, since this tends to increase the irritation and the affected area; and go to your physician, who will prescribe medication. Serious cases of plant poisoning may require special shots and even hospitalization.

6-48. **Animal Bites.** Animal bites can be serious. Don't take chances. Go to a doctor. If there is a chance that the animal is rabid, take rabies shots. Any animal bite has a tendency to become infected.

6-40. **Insect Bites.** Insect bites are the source of many communicable diseases. These bites often become infected and have to be treated accordingly. The spider, centipede, and scorpion are commonly thought of as insects, but biologically they are not. The black widow spider and the fiddle-back spider are poisonous. People bitten by them should have immediate medical attention. Stings from bees, wasps, ants, and other insects are painful and have, in some instances, caused death.

6-50. **Poisonous Snake Bites.** You often hear the expression "Snake bite medicine," in regard to whiskey; but don't use it. Poisonous snakes in the United States include the diamondback rattlesnake, the timber rattlesnake, the massasauga (pygmy rattlesnake), the Pacific rattlesnake, the watermoccasin, the copperhead, and the coral snake.

a. Prevention—In snake-infested country, watch where you step, where you place your hands, and where you sit. Wear high boots or stout leggings. Take care when picking berries and flowers and when climbing ledges.

b. Symptoms—Pain is immediate if pit viper venom is injected into the body. The poisoned part swells and becomes discolored. Coral snake venom causes only a slight burning and mild swelling at the wound. With the absorption of the poison, there is general weakness, shortness of breath, nausea and vomiting, a weak and rapid pulse, and

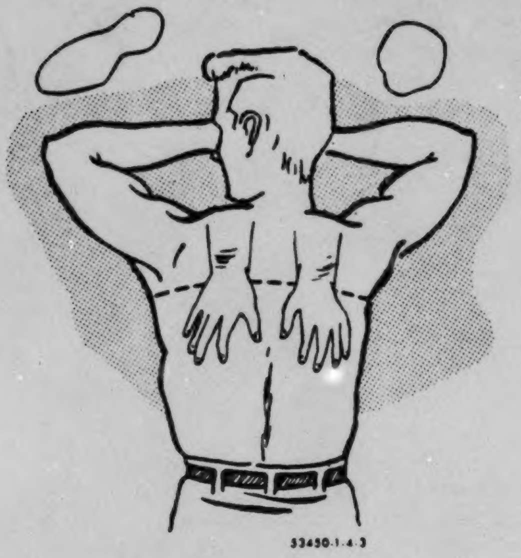


Figure 13. Back-pressure arm-lift artificial respiration.

perhaps dimness of vision. Unconsciousness may occur.

c. First aid—Have the patient to stop all muscular activity at once. Tie a constricting band above the bite if it is on the hand, foot, or leg. Sterilize a knife blade and make ¼-inch incisions at the wound in the figure of an X. Apply suction, using the mouth, or suction cup. (Don't swallow the venom, even though it is not a stomach poison.) (The mouth should be free of sores or cuts of any kind.) Get medical care as soon as possible.

6-51. **Heat Stroke, Heat Exhaustion, and Heat Cramps.** Exposure to excessive heat may result in heat exhaustion, heat stroke, or heat cramps. In exhaustion cases the temperature is approximately normal; in stroke it is high.

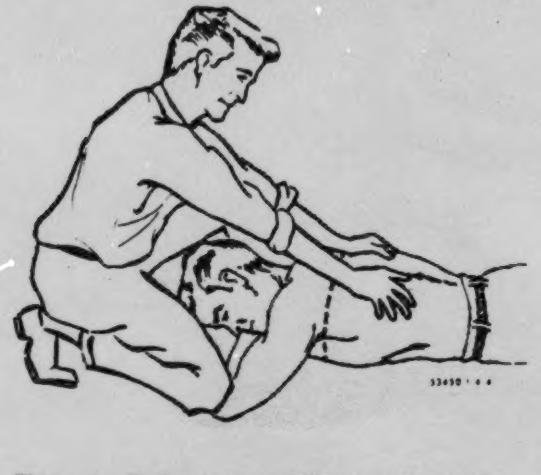


Figure 14. Back-pressure arm-lift artificial respiration.

- Prevention—Preventive measures include normal activity, proper clothing, sufficient body fluids, proper diet, and good environment. The replacement of body fluids lost through perspiration plus necessary salt helps to prevent heat exhaustion and stroke.
- First aid—In the case of heat exhaustion, sufficient rest is recommended. In the case of heat stroke, medical aid is urgently needed. Keep the patient lying down and quiet. Sponge the patient's body with alcohol or lukewarm water to prevent extreme temperature, and give only small doses of fluids and salt. Heat cramps often accompany heat exhaustion. They involve the abdominal and limb muscles. First aid is to apply firm pressure to the affected parts. Application of warm, wet towels

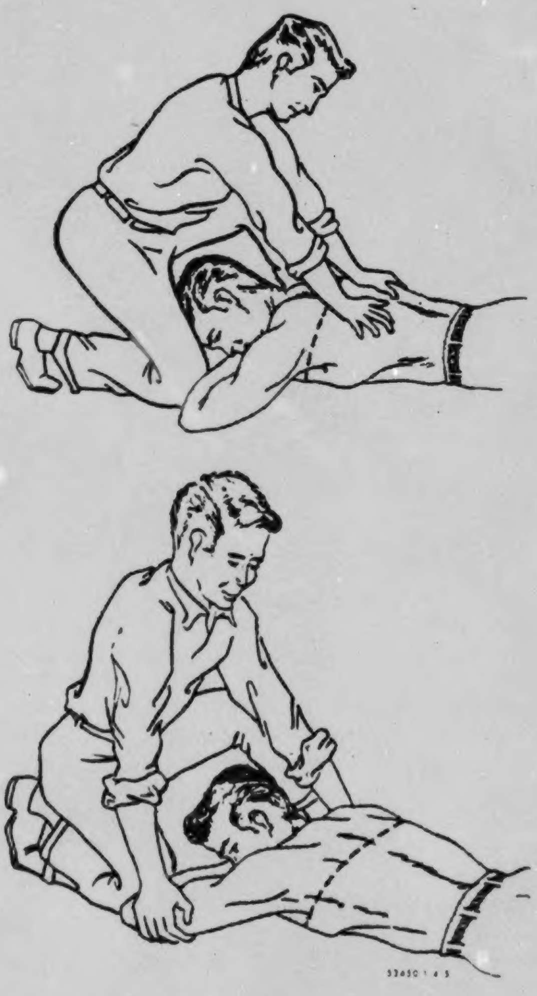


Figure 15. Back-pressure arm-lift artificial respiration.

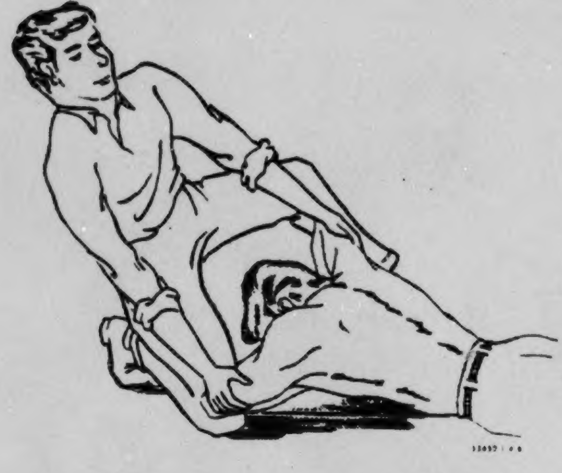


Figure 16. Back-pressure arm-lift artificial respiration

gives relief to the cramping muscles. Salt water solution may be given to restore body fluids and chemicals.

6-52. **Artificial Respiration.** Artificial respiration is used to restore breathing to normal when a person has either ceased to breathe or is breathing inadequately. This can be determined by observing the victim's color, which may be pale or blue, indicating oxygen starvation. It is important in any method of artificial respiration that the air passage be open. Obstruction of the air passage may be caused by liquids, false teeth, or other foreign matter; relaxation of the jaw which causes the tongue to fall backward, resulting in the condition commonly called "swallowing the tongue"; and an unnatural position of the neck called "kinking." The two recognized ways of administering artificial respiration are the back-pressure arm-lift, and mouth-to-mouth (or mouth-to-nose) methods. You should know how to use both methods. The mouth-to-mouth method is considered to be the best method in most cases.

6-53. *Back-pressure arm-lift method.* This method of artificial respiration can be used unless the victim has an injury such as a broken arm or a chest injury. Position the victim in a face-down position. Bend his elbows, turn his head to one side, and place his cheek on his hands. Remove any foreign matter from his mouth and pull his tongue forward. Kneel at the head of the victim on either the right or left knee. Place your knee close to the patient's head. Place your opposite foot near his elbow. You may kneel on both knees if you wish. Use the following steps:

(1) To begin the back-pressure arm-lift method, place both of your hands on the victim's back (see figs. 13 and 14).

(2) Rock forward until arms are about vertical. Do not bend the elbows (see fig. 15).

(3) Grasp victim's arms just above the elbows (see fig. 16).

(4) Rock backwards, keeping your arms straight—repeat the cycle in a rhythmic manner. For an adult, the cycle should be repeated about 12 times per minute. For a child, about 20 times per minute is recommended.

6-54. *Mouth-to-mouth artificial resuscitation.* To keep the air passage open, place the victim's head in the looking upward position. Hold his lower jaw forward in a sword-swallowing position. Clear the mouth and proceed in the following manner:

(1) Close the victim's nose by compressing it between the thumb and forefinger of the right hand.

(2) Take a deep breath and cover the victim's open mouth with yours. Make an airtight contact. Blow rapidly until his chest rises.

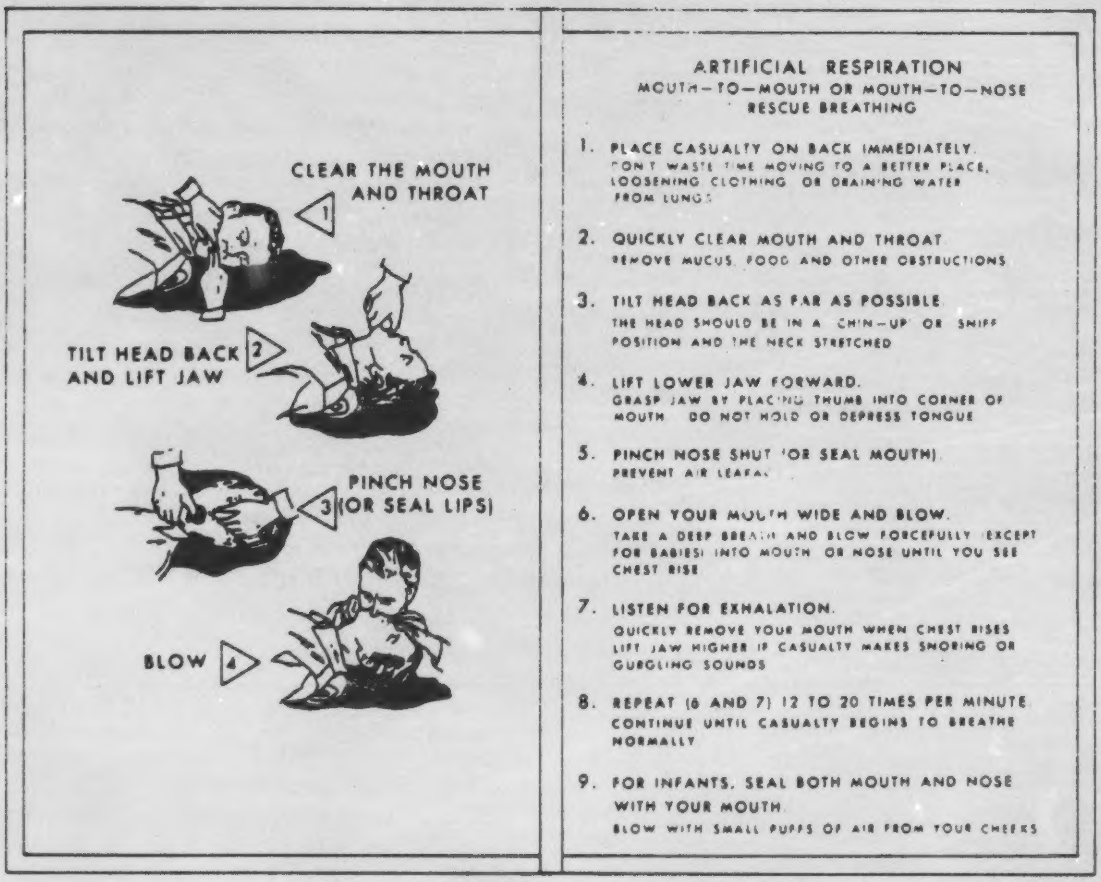
(3) After the chest rises, quickly separate lip contact with the victim. Allow him to exhale by himself.

(4) Perform the above operation 12 times per minute for an adult and 20 times per minute for a child. This must be continued until a mechanical resuscitator is secured or the victim is able to breathe on his own. Watch the victim until he is completely recovered. See fig. 17 for illustrations concerning mouth-to-mouth resuscitation techniques.

6-55. **Accident Reporting.** Accident/Incident reports provide Air Force agencies with detailed information concerning mishaps. Action can then be taken to prevent recurrences of the same mishap.

6-56. *The report.* Proper reporting is extremely important. The report must include the date of occurrence, the vehicles/material involved, the base code and report serial number, the place of occurrence, the time of the accident, the organization possessing the vehicle or material concerned, the base or command submitting the report, a complete list of personnel directly involved, a narrative description of the incident, and the cause of the accident. The report must be authenticated by the president of the investigating board. See figure 18 for sample USAF Accident/Incident Report.

6-57. *Action.* The action based on reports of investigation is not limited to base or operating level. Intermediate echelons, major commands, and HQ USAF are vitally interested in reports of accident/incident investigations. Individually and collectively, the accident and incident reports may be used as a basis for modifications and design cri-


CLEAR THE MOUTH AND THROAT
1
TILT HEAD BACK AND LIFT JAW
2
PINCH NOSE (OR SEAL LIPS)
3
BLOW
4

ARTIFICIAL RESPIRATION
MOUTH—TO—MOUTH OR MOUTH—TO—NOSE
RESCUE BREATHING

1. PLACE CASUALTY ON BACK IMMEDIATELY.
   DON'T WASTE TIME MOVING TO A BETTER PLACE, LOOSENING CLOTHING OR DRAINING WATER FROM LUNGS
2. QUICKLY CLEAR MOUTH AND THROAT.
   REMOVE MUCUS, FOOD AND OTHER OBSTRUCTIONS
3. TILT HEAD BACK AS FAR AS POSSIBLE.
   THE HEAD SHOULD BE IN A "CHIN—UP" OR "SNIFF" POSITION AND THE NECK STRETCHED
4. LIFT LOWER JAW FORWARD.
   GRASP JAW BY PLACING THUMB INTO CORNER OF MOUTH. DO NOT HOLD OR DEPRESS TONGUE
5. PINCH NOSE SHUT (OR SEAL MOUTH).
   PREVENT AIR LEAKAGE
6. OPEN YOUR MOUTH WIDE AND BLOW.
   TAKE A DEEP BREATH AND BLOW FORCEFULLY (EXCEPT FOR BABIES) INTO MOUTH OR NOSE UNTIL YOU SEE CHEST RISE
7. LISTEN FOR EXHALATION.
   QUICKLY REMOVE YOUR MOUTH WHEN CHEST RISES. LIFT JAW HIGHER IF CASUALTY MAKES SNORING OR GURGLING SOUNDS
8. REPEAT (6 AND 7) 12 TO 20 TIMES PER MINUTE.
   CONTINUE UNTIL CASUALTY BEGINS TO BREATHE NORMALLY
9. FOR INFANTS, SEAL BOTH MOUTH AND NOSE WITH YOUR MOUTH.
   BLOW WITH SMALL PUFFS OF AIR FROM YOUR CHEEKS

53450—1—4—7

Figure 17. Mouth-to-mouth artificial respiration.

teria changes. Collectively, accident/incident reports provide information used in operations planning and other staff actions. These may be obscure to the investigation board on the basis of one single incident.

6-58. *Recommendations.* The report must be prepared with the knowledge that personnel at various Air Force levels will review the report, evaluate the findings, and take appropriate action. The action usually takes the form of recommendations or directives designed to reduce accidents. If the report is prepared with the viewpoint restricted to local base capabilities, the effectiveness of the accident/incident reporting system is limited.

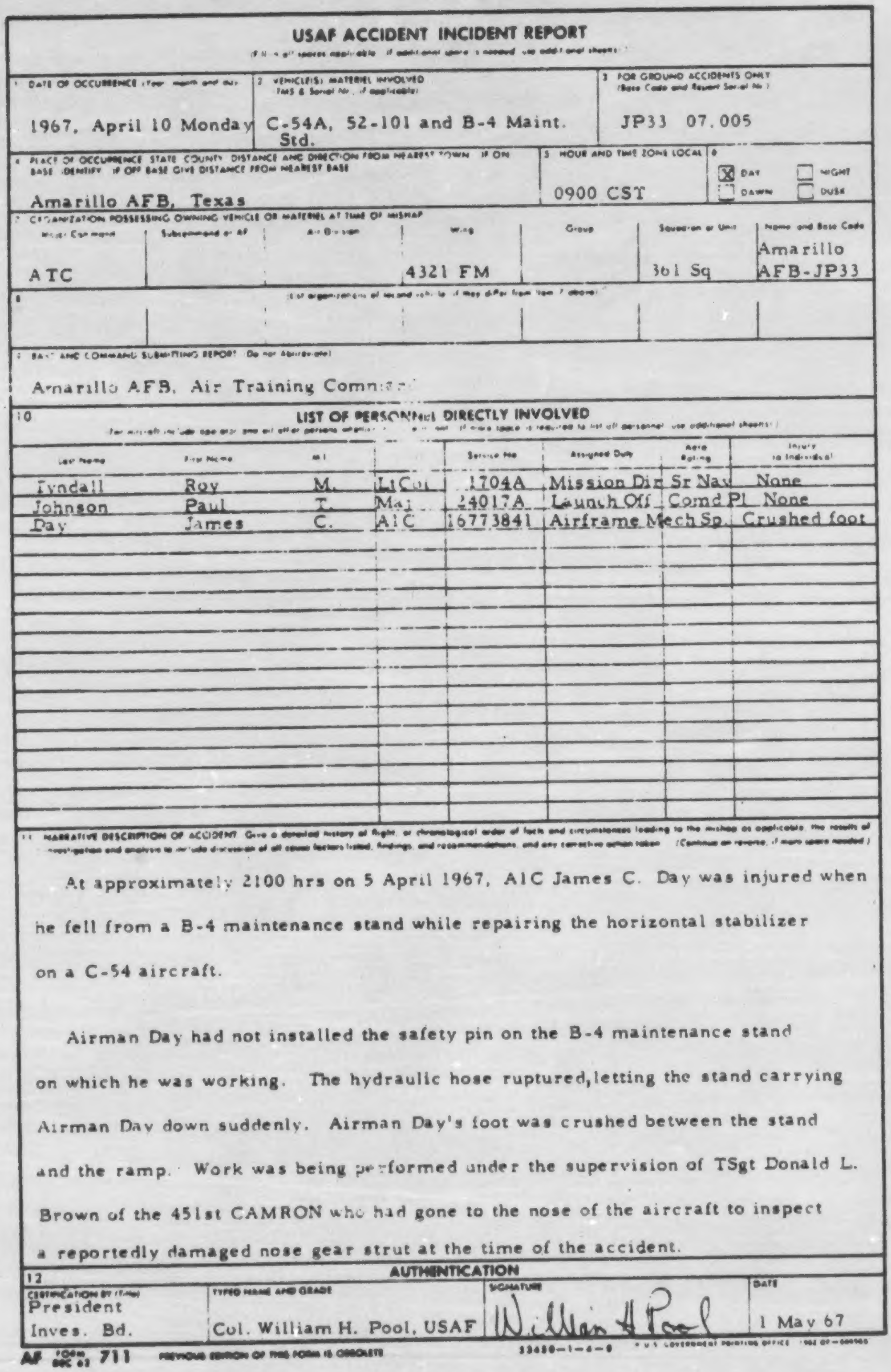
7. Shop Safety

7-1. The airframe repair shop where you work is only as safe as the people who work there and the machines they operate. A good workman is a safe worker. He does his job efficiently and observes necessary safety precautions.

7-2. **Handling Chemicals and Chemical Solutions.** Atmospheric contaminants are health hazards. They consist of dusts, gases, fumes, and vapors. They are present in several areas of the airframe repair shop.

7-3. *Dusts.* These are caused by dry acids and compounds such as chronic acid, sodium dichromate, and ammonium bifluoride. These dusts can cause skin ulcers. They may also be breathed into the lungs, where they can cause irritation. These dusts on the skin can be activated by perspiration, which causes irritation. Use exhaust fans in dust-producing areas. Also use breathing masks and articles of protective clothing that are provided.

7-4. *Gases and vapors.* A gas is a substance which exists as a gas in its normal state, at normal temperatures and pressures. A vapor is the gas given off from a substance which is normally a liquid. Vapors can also be emitted from a solid if it is heated. Gases are generally lighter than air, whereas vapors are heavier than air. Density of the molecules controls the heaviness or lightness of a substance. Gases and vapors are divided into four groups, depending on their effects on the body.



USAF ACCIDENT INCIDENT REPORT

(Fill in all spaces applicable. If additional space is needed use additional sheets.)

1 DATE OF OCCURRENCE (Year, month and day) 1967, April 10 Monday	2 VEHICLE(S) MATERIEL INVOLVED (TMS & Serial No., if applicable) C-54A, 52-101 and B-4 Maint. Std.	3 FOR GROUND ACCIDENTS ONLY (Base Code and Report Serial No.) JP33 07.005

4 PLACE OF OCCURRENCE STATE COUNTY DISTANCE AND DIRECTION FROM NEAREST TOWN. IF ON BASE IDENTIFY. IF OFF BASE GIVE DISTANCE FROM NEAREST BASE Amarillo AFB, Texas	5 HOUR AND TIME ZONE LOCAL 0900 CST	6 ☒ DAY ☐ NIGHT ☐ DAWN ☐ DUSK

7 ORGANIZATION POSSESSING OWNING VEHICLE OR MATERIEL AT TIME OF MISHAP

Major Command	Subcommand or AF	Air Division	Wing	Group	Squadron or Unit	Name and Base Code
ATC			4321 FM		361 Sq	Amarillo AFB-JP33

8 (List organizations of second vehicle if they differ from item 7 above)

9 BASE AND COMMAND SUBMITTING REPORT (Do not Abbreviate)

Amarillo AFB, Air Training Command

10 **LIST OF PERSONNEL DIRECTLY INVOLVED**

(For aircraft include operator and all other persons aboard. If more space is required to list all personnel use additional sheets.)

Last Name	First Name	M.I.		Service No	Assigned Duty	Aero Rating	Injury to Individual
Tyndall	Roy	M.	LtCol	1704A	Mission Dir	Sr Nav	None
Johnson	Paul	T.	Maj	24017A	Launch Off	Comd Pl	None
Day	James	C.	A1C	16773841	Airframe Mech Sp.		Crushed foot

11 NARRATIVE DESCRIPTION OF ACCIDENT. Give a detailed history of flight, or chronological order of facts and circumstances leading to the mishap as applicable, the results of investigation and analysis to include discussion of all cause factors listed, findings, and recommendations, and any corrective action taken. (Continue on reverse, if more space needed.)

At approximately 2100 hrs on 5 April 1967, A1C James C. Day was injured when he fell from a B-4 maintenance stand while repairing the horizontal stabilizer on a C-54 aircraft.

Airman Day had not installed the safety pin on the B-4 maintenance stand on which he was working. The hydraulic hose ruptured, letting the stand carrying Airman Day down suddenly. Airman Day's foot was crushed between the stand and the ramp. Work was being performed under the supervision of TSgt Donald L. Brown of the 451st CAMRON who had gone to the nose of the aircraft to inspect a reportedly damaged nose gear strut at the time of the accident.

12 **AUTHENTICATION**

CERTIFICATION BY (Title) President Inves. Bd.	TYPED NAME AND GRADE Col. William H. Pool, USAF	SIGNATURE William H Pool	DATE 1 May 67

AF FORM DEC 63 711 PREVIOUS EDITION OF THIS FORM IS OBSOLETE 33430—1—4—8 U.S. GOVERNMENT PRINTING OFFICE

Figure 18. AF Form 711.

7-5. Asphyxiants are gases or vapors which, when breathed, cut off the oxygen to the lungs. Some of the asphyxiants are methane, hydrocarbon vapors, hydrogen, nitrous oxide, acetylene, and the inert gases. Chemical asphyxiants, such as cyanogen compounds and carbon, prevent the human blood from absorbing oxygen by filling the bloodstream with large amounts of asphyxiants.

7-6. Irritant gases and vapors cause inflammation of the respiratory system. These may cause pneumonia or other pulmonary diseases. Some of the irritating gases and vapors are ammonia, chlorine, sulphur dioxide, hydrogen sulphide, hydrochloric acid, nitrogen oxides, phosphorus, and arsenic trichloride. These vapors and gases are not only hazardous as irritants but are also toxic. Use a breathing mask designed to be worn while working around these gases and vapors. Wear designated protective clothing, such as gloves, etc.

7-7. Anesthetics are gases and/or vapors that have a narcotic or druglike effect on people. The central nervous system becomes dangerously depressed. Respiratory failure may occur, and death may result. Most narcotic gases and vapors belong to the hydrocarbon series. They include formaldehyde, methyl ether, ethyl ether, gasoline, naphtha, benzene, propylene, dimethyl ketone, methyl acetate, ethyl acetate, carbon tetrachloride, and other related substances.

7-8. Poisonous gases and vapors act directly on the body and injure or destroy the visceral organs. They also may injure or destroy the blood-forming system, tissues, or bones. This will depend on the type of gas or vapor involved. Some of these are methyl chloride, methyl bromide, ethyl chloride, ethyl bromide, certain alcohol compounds, and tetraethyl lead.

7-9. *Fumes.* Fumes are particles usually resulting from the condensation of substances that have been heated or burned. They may be produced from chemical or metallurgical processes, molten metal, or decomposition. The term "fumes" is often misused, erroneously being considered as gases and vapors. Fumes present health hazards in many ways, depending on their source. The fumes produced from metals such as lead, zinc, cadmium, and manganese are particularly harmful. The fumes may not be present during normal working conditions but can be created by combining various substances. If a piece of zinc is placed in a container of hydrochloric acid, the zinc displaces the hydrogen, which being lighter than air, rises in the form of bubbles. The gas thus formed is not only an asphyxiant but is an explosive as well. It is very important that only authorized mixtures of substances be made. Only authorized personnel are allowed to handle or mix hazardous chemicals. These authorized personnel must wear breathing masks, rubber gloves, and other protective clothing.

7-10. *Paint removers.* Most paint removers have an alkali base. They are very caustic in nature and will burn the skin upon contact. Most serious accidents caused by paint removers occur when the container is being opened. Heat causes the contents to expand; and when the cap is removed, paint remover sprays out and injures the eyes. To eliminate this possibility, be sure the paint remover can is cooled to room temperature. Place the opening of the can uppermost before removing the cap. Always wear a protective face mask and protective clothing to insure maximum safety.

7-11. **Safety Equipment.** Personal safety equipment consists of safety items worn by personnel and include such items as rubber gloves, aprons, boots, and face shields. Laboratory or shop safety equipment includes ventilating fans and hoods, emergency showers and eyewash fountains, and fire extinguishers.

7-12. Safety equipment, though effective, is useless if it is not properly used. Keep your safety equipment clean and in good repair. A dirty face mask or shield, or a leaking stove, can defeat the purpose of the device.

7-13. **Storage, Handling, and Use of Chemicals.** Proper storage of the many chemicals used around the airframe repair shop is necessary. The prevention of possible fires, injury to personnel, and possible freezing of materials is important. Acids must be stored away from possible ignition sources. They must be stored in carboys that are separated from each other. The breakage of acid containers could cause acid to come into contact with organic materials and result in a fire. Solvents and paint removers should be stored at room temperature to prevent freezing or overheating.

7-14. Handling of acids is hazardous. Acid should be poured from the carboy with the aid of a tilter or siphon. If a siphon is used, the fluid flow should be started by using a rubber squeeze bulb. Never add water to acid; instead, add acid to water. Water poured into acid may cause an explosion. Keep floors clear of obstacles to prevent tripping. Always replace acid container caps immediately after use. Maintain a businesslike atmosphere wherever chemicals are stored or used. Tolerate no horseplay. Rinse all rags and brushes after use to prevent spontaneous combustion. Wear rubber gloves, rubber apron, rubber boots, and a breathing mask. These protective devices will prevent contact with the acid and keep you from inhaling the fumes.

7-15. **Fire Extinguishers.** Discussion on the various types of fire extinguishers was covered in paragraph 6-6. The type, size, and number of fire

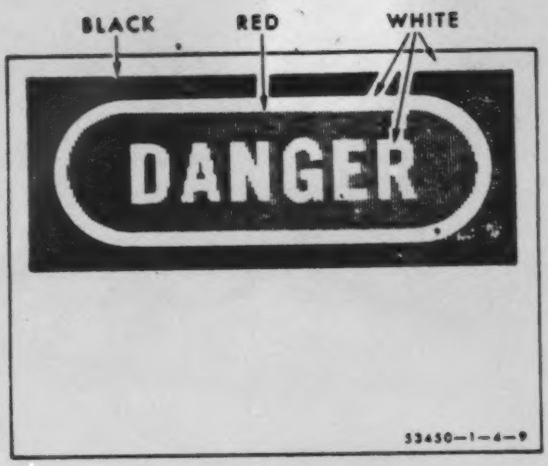


Figure 19. Accident protection signs.

extinguishers in a shop are determined by Air Force regulations. The Base Fire Department is responsible for servicing and inspecting these extinguishers. Your shop shares the responsibility of fire safety and training in the proper use of fire extinguishers.

7-16. **Warning Signs.** You have probably heard the expression, "Signs of the times." Warning signs are placed in various areas of your shop for your protection. Observe them!

7-17. In order for safety signs to be completely effective, reaction to them should be automatic. It should not be necessary for a person to stop, read, and analyze the meaning of each sign. Most safety signs have been made uniform, especially in color and shape. In some areas "SMOKING PERMITTED" signs are found, whereas in others "NO SMOKING" signs are placed in conspicuous places. Danger signs are red, caution signs are yellow, safety signs are green, and directional and informational signs are black and white (see figs. 19–22).

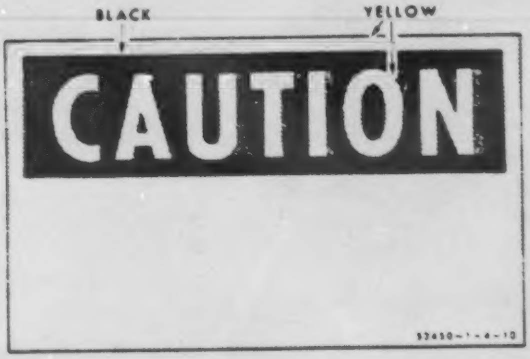


Figure 20. Accident protection signs.

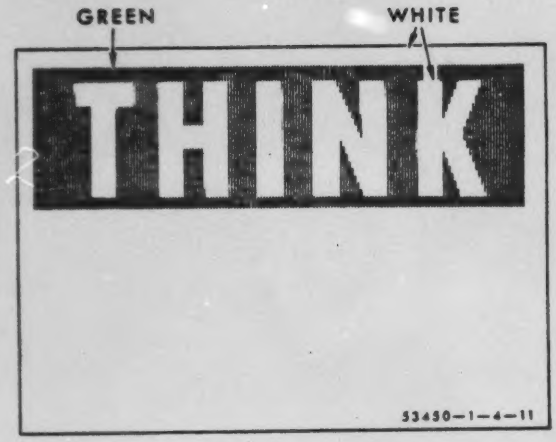


Figure 21. Accident protection signs.

7-18. **Hazardous Wearing Apparel.** Many jobs done by airframe repair personnel require special protective articles. There are some items of wearing apparel that are dangerous; thus, you are forbidden to wear them. Some of these articles are as follows:

- Ragged or loose-fitting clothing.
- Worn or improper size gloves.
- Loose-fitting face mask.
- Static-producing clothing around flammable material.
- Soft-toe shoes when hard-toe are required.
- Greasy clothing when working around oxygen.
- Watches, rings, and other types of jewelry.
- Neckties.

7-19. **Fire Hazards.** There are many fire hazards in an airframe repair shop. Some of these are:

- Overheated electrical motors.
- Overloaded electrical circuits.
- Improper mixing and handling of chemicals.

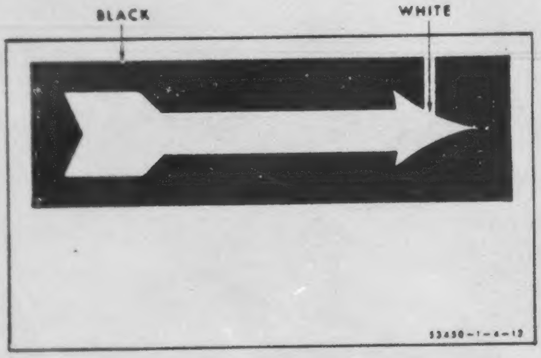


Figure 22. Accident protection signs.

- Smoking in a "No Smoking" area.
- Using unauthorized cleaning materials.
- Poor housekeeping practices, such as allowing waste to accumulate.
- Improper handling of bottled gas containers, such as dropping them and breaking the valves off.
- Inadequate ventilation, which allows collection of explosive dusts and vapors.

7-20. **Safe Handling of Metal Stocks.** In the airframe repair shop, you use various types of metal stocks. We are concerned with the safe handling of these for the protection of the materials and the personnel handling them.

7-21. *Handling the material.* All aluminum sheet and plate is to be stored in a dry, fully inclosed space. It is not to be exposed to weather and other corrosion-inducing conditions. Corrosion renders the material unserviceable for the use that it was designed for. Aluminum should never be stored when it is wet, but must be dried first. The storage area for aluminum must be dry and must be kept that way. To prevent scratches or other marks on aluminum, avoid contact between it and other materials. Keep metal stocks away from chemicals such as caustics, nitrates, phosphate, and most acids. Stocks of sheet metal, if stored in shelves, must have a paper layer between the sheets to prevent scratching. Sheet metal should be placed in separate stacks according to the type, size, and thickness.

7-22. *Safety for the handler.* The safety precautions applicable to the safe handling of metal stocks mostly involve common sense. Wear leather gloves. Have help in handling large sheets. Be careful when picking up and letting down sheets of metal stock. Watch for sharp corners and edges.

7-23. **Protection from Chemicals.** In corrosion control, plastic enclosure patching, and plastics working, several types of chemicals are used. The people using these chemicals and those exposed to their fumes must wear protective equipment. These protective devices are in two general classes.

7-24. *Chemical contact protection.* The type of protective equipment or clothing depends on the nature of the operation. Equipment used to protect personnel from chemical contact are rubber gloves, rubber aprons, rubber boots, goggles, and coveralls.

7-25. *Chemical fume protection.* Severe physical effects and possible damage can result from breathing chemical fumes. The protective devices for this hazard include breathing masks—self-contained or otherwise—and ventilating systems.

7-26. *Chemical vapor ignition.* Many of the chemicals used in the airframe repair shop give off flammable vapors. The concentration of these vapors in proper proportion to air presents an explosive hazard. Static sparks, mechanical sparks, and stray electrical sparks can cause ignition of these chemical vapors.

7-27. *Chemical injuries.* Chemical injuries are to be regarded as emergencies and treated as such. Most chemicals can be washed off with large quantities of water. The person who has come into contact with such chemicals should then be taken to the doctor for possible medical observation and treatment.

7-28. For symptoms and emergency treatment of chemical injuries see paragraphs 6-43 and 6-44.

8. Aircraft Ground Safety

8-1. Our Air Force is equipped with three general types of aircraft. These are of varied sizes and shapes and are powered by engines, either jet or reciprocating. Their range, payload, and maneuverability differ according to their purpose. We as airframe repairmen and/or technicians are concerned with safety in and around these aircraft.

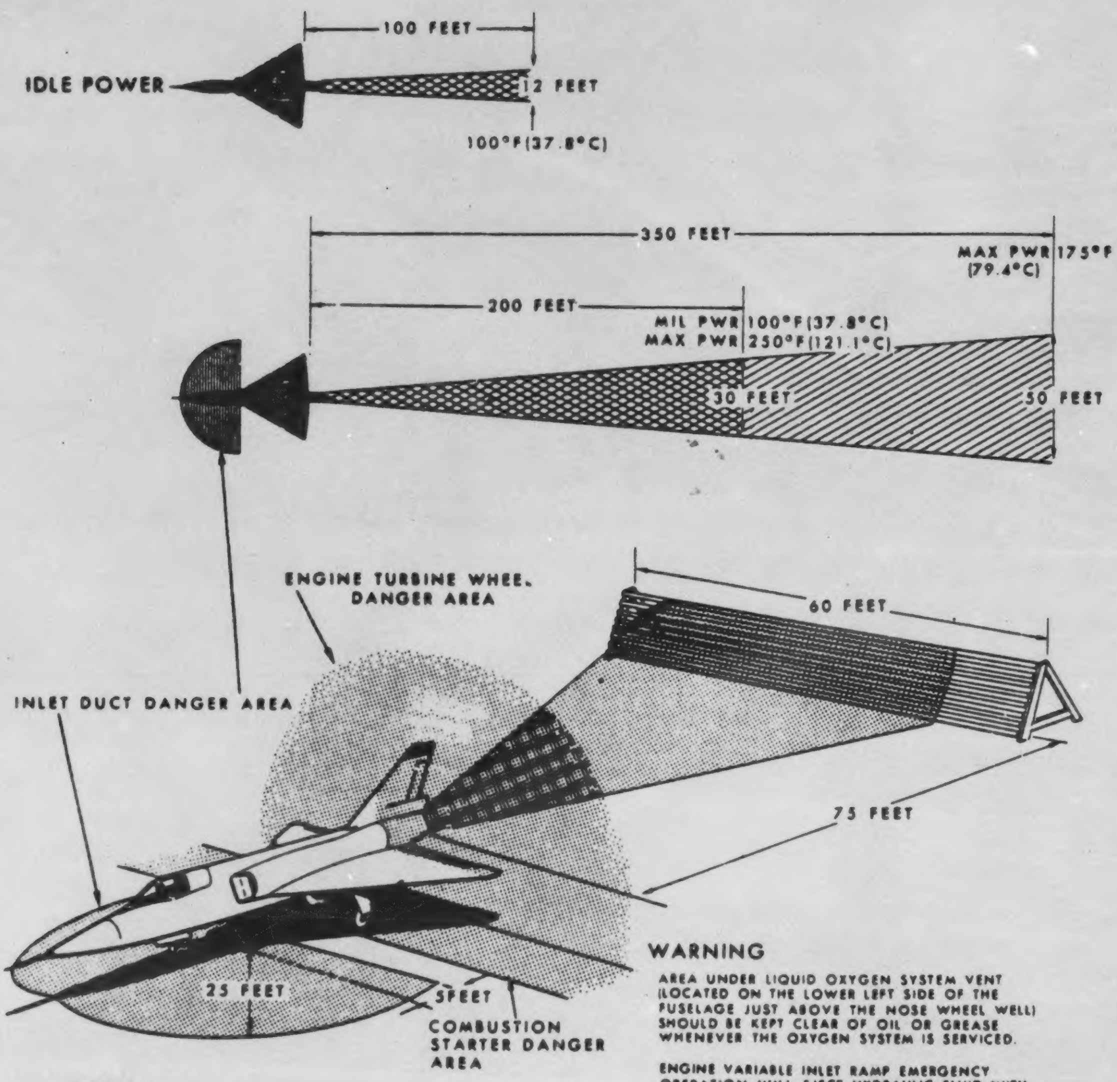
8-2. **External Danger Areas.** Certain areas around the various types of aircraft are dangerous, and these dangers must be known by all personnel concerned.

8-3. *Jet engine intakes and exhaust.* When the engine is running, intakes are hazardous within 25 feet. They may have guard screens, but you can still be injuried by being sucked against the screen. The area of jet engine exhaust is a hot place to be and is considered hazardous within 200 feet. The hot exhaust is not the only hazard, since the blast of air can do damage to you if it hits you or stirs up dirt or other particles in your face. The distance depends upon the type of aircraft involved.

8-4. *Jet engine turbine wheels.* There is a red strip painted on the fuselage or nacelle of jet aircraft. This strip marks the plane of the turbine wheel rotation, which is hazardous in case the turbine fails. See figures 23 and 24 for jet aircraft danger areas.

8-5. *Reciprocating aircraft propellers.* People have had their heads split open by aircraft propellers. The engine may be turned off and the propeller stopped, but for some reason it may be ticked over enough to injure you. A rotating propeller seems to exert a hypnotic effect on people which causes them to walk into the propeller. Propeller wash has often thrown dirt and other particles into people's eyes. Do not stand within 25 feet of the front of a rotating propeller. Do not stand directly in the line of the propeller wash.

8-6. *Helicopter rotor blades.* The hazards of helicopter rotor blades are very similar to those of reciprocating aircraft propellers. Stand clear until


100 FEET
IDLE POWER
12 FEET
100°F(37.8°C)
350 FEET
MAX PWR 175°F (79.4°C)
200 FEET
MIL PWR 100°F(37.8°C)
MAX PWR 250°F(121.1°C)
30 FEET
50 FEET
ENGINE TURBINE WHEEL DANGER AREA
60 FEET
INLET DUCT DANGER AREA
75 FEET
25 FEET
5FEET
COMBUSTION STARTER DANGER AREA

WARNING

AREA UNDER LIQUID OXYGEN SYSTEM VENT (LOCATED ON THE LOWER LEFT SIDE OF THE FUSELAGE JUST ABOVE THE NOSE WHEEL WELL) SHOULD BE KEPT CLEAR OF OIL OR GREASE WHENEVER THE OXYGEN SYSTEM IS SERVICED.

ENGINE VARIABLE INLET RAMP EMERGENCY OPERATION WILL EJECT HYDRAULIC FLUID WITH CONSIDERABLE FORCE FROM AN OVERBOARD DRAIN LINE LOCATED UNDER THE LEFT HAND ENGINE INTAKE DUCT.

THE ENGINE BLEED AIR DISCHARGE DUCTS (LOCATED ON THE LEFT AND RIGHT FUSELAGE SIDES ABOVE THE WINGS) DISCHARGE HOT AIR DURING ENGINE OPERATION.

KEEP CLEAR OF AREA 10 FEET FORWARD AND AFT OF MAIN LANDING GEAR UNTIL COMBUSTION START HAS BEEN COMPLETED. AT NO TIME WILL THE IGNITION BUTTON BE DEPRESSED AND THE THROTTLE MOVED OUTBOARD WITH PERSONNEL IN THE ENGINE COMPARTMENT.

NOTE:

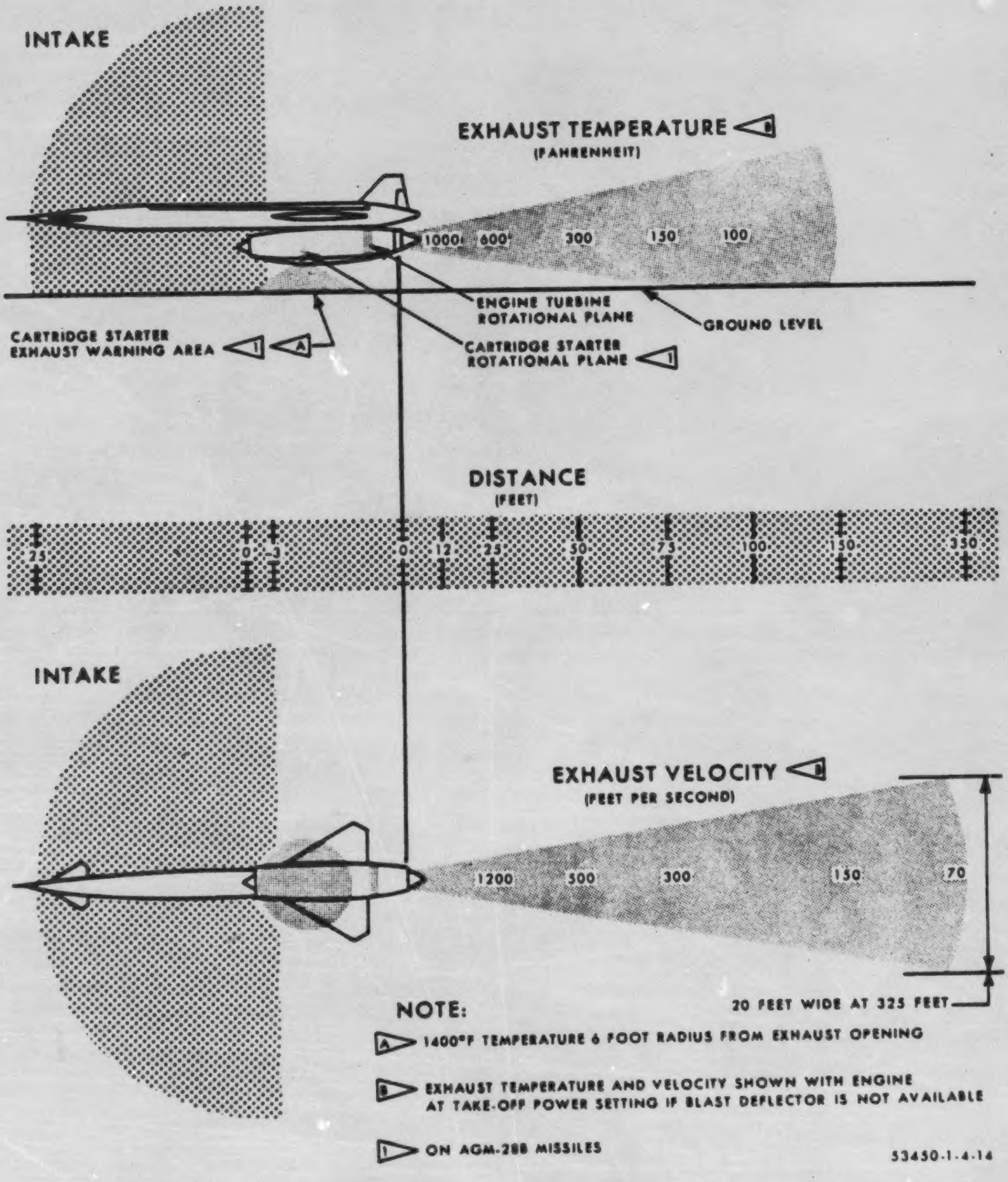
AREA MUST BE CLEAR AT LEAST 350 FEET IF BLAST DEFLECTOR IS NOT AVAILABLE, BEHIND THE AIRPLANE.

53450-1-4-13

Figure 23. Jet aircraft danger areas (fighter aircraft).

you are sure the rotor is stopped before you approach this type of aircraft. The downdraft can cause serious facial damage from dirt and debris.

8-7. *Aircraft noise hazards.* Serious damage to your ears can result from exposure to the high-intensity noise of jet engines. Wear the prescribed ear defenders if you work in a noise hazard area on the flightline. The type of ear defender needed is prescribed by the base surgeon. Ear defenders are available through Air Force supply channels. These devices consist of ear plugs, muffs, helmets, or a combination thereof. Personnel working in


INTAKE
EXHAUST TEMPERATURE B
(FAHRENHEIT)
1000
600
300
150
100
ENGINE TURBINE ROTATIONAL PLANE
GROUND LEVEL
CARTRIDGE STARTER EXHAUST WARNING AREA 1 A
CARTRIDGE STARTER ROTATIONAL PLANE 1
DISTANCE
(FEET)
25
0
-3
0
12
25
50
75
100
150
350
INTAKE
EXHAUST VELOCITY B
(FEET PER SECOND)
1200
500
300
150
70
20 FEET WIDE AT 325 FEET

NOTE:

A 1400°F TEMPERATURE 6 FOOT RADIUS FROM EXHAUST OPENING

B EXHAUST TEMPERATURE AND VELOCITY SHOWN WITH ENGINE AT TAKE-OFF POWER SETTING IF BLAST DEFLECTOR IS NOT AVAILABLE

1 ON AGM-28B MISSILES

53450-1-4-14

Figure 24. Jet aircraft danger areas (bomber aircraft).

noise hazard areas are required to have audiometric examinations in accordance with AFR 160–3 (see fig. 5-12 of this AFR). High-intensity noise can cause one to become ill. Some of the symptoms of damage due to high-intensity noise are pain, feeling of fullness, dizziness, ringing or burning of the ears, impairment of mental concentration, nausea, vomiting, weakness of the knees, and general disruption of normal actions. If an individual has any of the above symptoms, he should be removed from the area at once. Medical examination is required for such personnel. The flight surgeon determines corrective measures for persons affected by noise hazards.

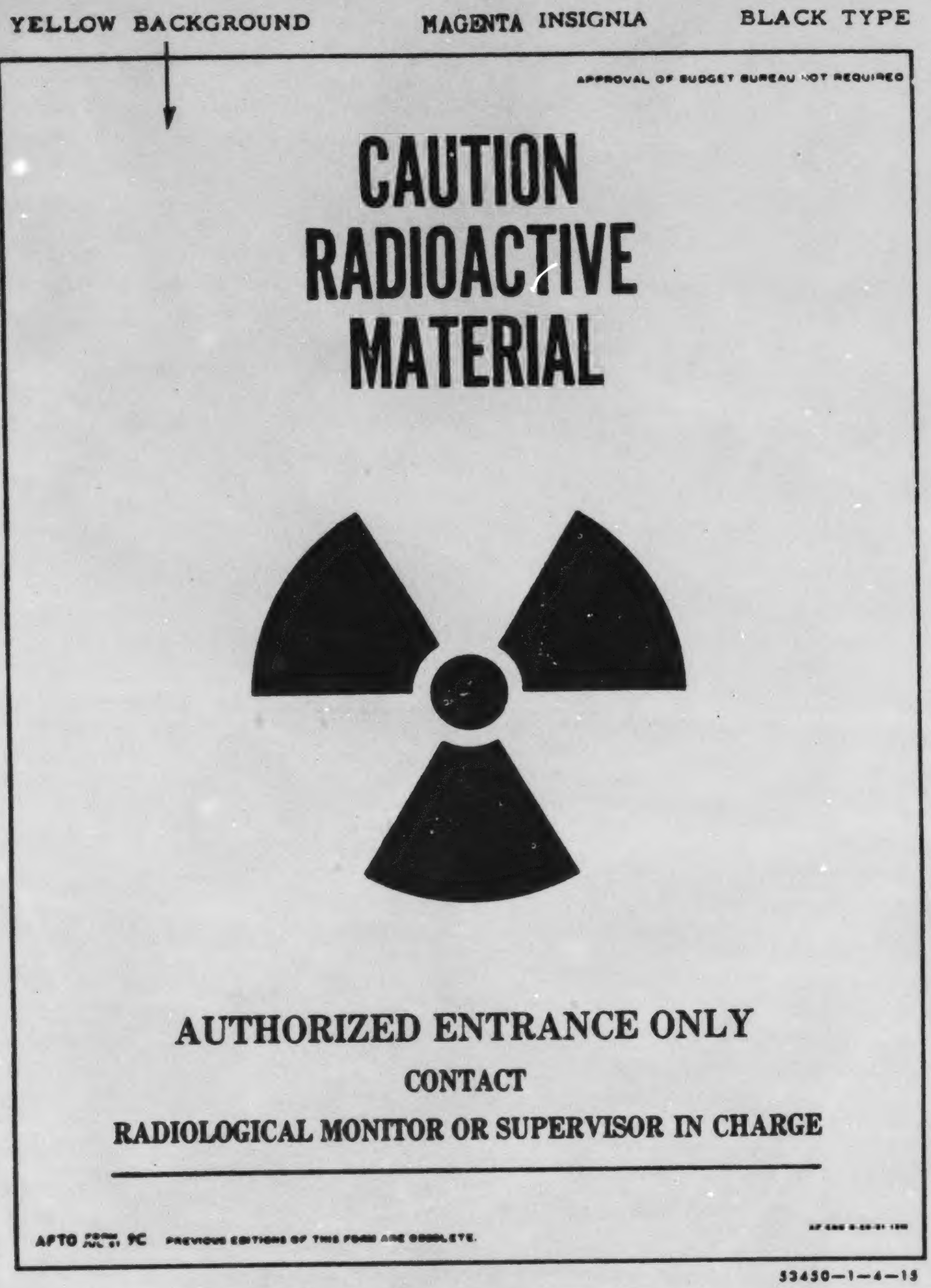

YELLOW BACKGROUND
MAGENTA INSIGNIA
BLACK TYPE
APPROVAL OF BUDGET BUREAU NOT REQUIRED
CAUTION
RADIOACTIVE
MATERIAL
AUTHORIZED ENTRANCE ONLY
CONTACT
RADIOLOGICAL MONITOR OR SUPERVISOR IN CHARGE
AFTO FORM JUL 61 9C PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE.
53450—1—4—15

Figure 25. Radioactive caution signs.

8-8. *Radiologically contaminated areas.* Because of possible widespread use of atomic power and nuclear weapons, you must know how to recognize situations involving radiation hazards. You must know what your responsibility is in monitoring operations using radioactive materials or aircraft suspected of being contaminated. You, as an airframe repair specialist or technician, must be able to recognize radioactive caution signs (see fig. 25). If you become accidentally contaminated, report to the radiological decontamination team at once.

8-9. *Hazardous walkways.* Walkways on our high-performance aircraft are marked to prevent damage. These walkways are not so hazardous to maintenance personnel, but misuse can increase the necessity for airframe repairs. You, as an airframe repair specialist or technician, must know where it is safe for you to walk on the aircraft. Control surfaces, trailing edges, wingtips, and other designated areas are easily damaged. Most of these are bonded honeycomb, and the metal skin covering is thin.

8-10. **Internal Danger Areas.** Because of the existence of switches, levers, handles, and other controls of aircraft functions, be very careful not to operate any of these things that are in the cockpit or fuselage.

8-11. *Ejection seats and canopies.* Ejection seats and canopies are controlled manually but are ejected by explosive charges. These explosive charges are normally set off by an igniter but may also be fired by heat. Each seat and canopy ejection system is protected from accidental firing by the installation of safety pins. These safety pins are installed when the aircraft is on the ground. They must be removed prior to flight. These ground safety pins have identifying red streamers attached to them. There may be more than one pin attached to one streamer. If you do airframe repairs in the cockpit, be sure the ground safety pins are installed. Do not use heat around these explosive charges. If heat is to be used in the area of these explosives, secure the services of an authorized armament specialist. He will remove the explosive catapult or otherwise disarm the ejection system until the airframe repairs are completed.

8-12. *Cockpit switches, levers, and control and column operation.* The airframe repair specialist or technician is not to operate the aircraft switches, levers, control column, or rudder pedals. The reason is that the battery switch can make possible the energizing of the fuel tank selector switch, the fuel dump valve switch, and the armament jettison or fire switch. The landing gear handle can cause the inadvertent collapse of the landing gear. Moving the control column or rudder pedals could cause serious injury to the hands of a mechanic who is working on the flight control system.

8-13. *Cockpit instruments, wiring, and tubing.* Modern aircraft are equipped with many important instruments. These are essential for use by the pilot and other crewmembers. Be careful not to damage these instruments. There are miles and miles of electrical wiring that terminate in the cockpit. Do not disturb wiring; if it is necessary for wiring to be moved, get an electrician to do it for you. Tubing of various sizes enters the cockpit. It is important that this not be damaged. Do not bend, break, or dent tubing.

8-14. *Hazards of tools and debris left in the cockpit.* Loose tools and debris left in the cockpit can cause falls and equipment malfunction. A wrench, screwdriver, or other tool can jam a control. Debris such as trash, paper, or other material can cause a malfunction. When you work in an aircraft cockpit, check to be sure you have all your tools. Police up before you leave your work area.

9. Aerospace Ground and Power Equipment Safety

9-1. Only fully qualified persons are authorized to start and operate ground power and auxiliary power units. The purpose of this requirement is to insure the safety of aircraft, equipment, and personnel.

9-2. The *Handbook of Operating Instructions* for each unit of ground power should be carefully adhered to. These instructions include emergency shutdown procedures and other precautionary measures, use of fire extinguishers, and operator maintenance and inspection instructions.

9-3. **Special Safety Precautions.** No power unit is to be operated within 50 feet of fueling operations or flammable spillage. Power units are to be positioned upwind of the aircraft and with the 60-foot power cables fully extended. No power unit is to be operated under any portion of the aircraft structure. Air compressors that are used for airframe repair operations are to be handled with care. Compressed air should never be used to blow dirt from your clothes or work area. Eye damage can result. Also, particles can become embedded in the skin. When compressed air is being used, operators should be careful to keep foreign material from entering the equipment. All compressors in daily use must be drained daily. Care is to be taken not to kink hose lines. They should be protected from damage due to being run over by vehicles. High-pressure compressors must be stenciled as such.

9-4. **Workstand Safety.** Inspections necessary to be made before using a workstand include presence and installation of guardrails that are in good repair, proper workstand for the job, proper operation of the hydraulic lift unit, and the presence and condition of the safety lock. All the above are for your personal safety as well as the safety of the aircraft and other persons. *Workstands must be kept free of oil and grease or any substance or object which could cause injuries through slips and falls.*

9-5. **Ground Power Operator's Permits.** The Chief of Maintenance establishes necessary internal controls to assure that only qualified personnel are allowed to operate aerospace ground power equipment. If desired or deemed necessary, the AFTO Form 35 can be used as a means to carry out or support the local controls. This form is designated primarily as an operator's permit for AGE.

9-6. The signature block of AFTO Form 35 must contain the signature of the issuing official. When additions are required and authorized by an official other than the one indicated by the original signature, the form will be updated to reflect the additional qualifications. Equipment Operation Authorized blocks must be signed by the training control representative.

9-7. The operator's permit is retained by the individual when he is transferred to another organization. Upon arrival at the new organization at which the AFTO Form 35 is used as part of the local control procedures, training control reviews the permit for recertification or reissue as deemed necessary. The training control official must initial above the original issuing officer's signature. Lost permits are replaced by the certifying official. He uses the individual's training records as a basis for reissuance of lost permits.

9-8. **AFTO Form 45, Status and Operating Record.** This form is referred to by the operator to determine the condition of and report the status of AGE.

9-9. You may say, "What if there is a need to use a unit of equipment not listed on the Operator's Permit, AFTO Form 35?" The answer is to contact workload control for loan of a qualified operator. The man from your shop must then be trained to operate the equipment. The supervisor must contact the training control section to secure training for this man so that he is qualified on the equipment needed.

2-3 29

53450 01 27

WORKBOOK

Fundamentals of Organization and Managment

SELF-TEACHING AIDS
CRE
VRE
SRG

This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Study Reference Guide, the Chapter Review Exercises and their answers, and the Volume Review Exercises. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, "Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

EXTENSION COURSE INSTITUTE

Air University

TABLE OF CONTENTS

Study Reference Guide

Chapter Review Exercises

Answers For Chapter Review Exercises

Volume Review Exercise

ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number	*Guide Numbers 100 through 111*
100	Introduction: Security of Classified Information; Physical and Communications Security; pages 1-3
101	Metalworking Career Field (53): pages 3-6
102	Introduction: Air Force Supply Discipline: Classification Procedure; . . .; Guides for Supply Cataloging, Part 1 (Cataloging Handbook H6-1): pages 7-10
103	Air Force Supply Discipline: Cross-Reference Indexes; . . .: AFM 67-1, Volume II, Part Two, Section E, Property Custodians' Responsibilities; pages 10-15
104	Air Force Supply Discipline: Purpose of Air Force Manual 67-1, USAF Supply System; . . ; Book of Standards; pages 15-17
105	Supply Management: pages 17-25
106	Introduction: Safety Practices: Disposal of Scraps and Waste, . . ., Off-the-Job Safety Precautions; pages 25-29
107	Safety Practices: First Aid, . . ., Accident Reporting; pages 29-34
108	Shop Safety: pages 34-38
109	Aircraft Ground Safety; Aerospace Ground and Power Equipment Safety; pages 38-43
110	Appendix A; pages 47-55
111	Appendix B: pages 56-60

* NOTE: Page 32 is missing due to deleted material. No pertinent information was omitted.

MODIFICATIONS

Pages 3-6 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 3

Sections 6 and 7

Objective: To have a knowledge of the hazards in the airframe repair shop and the precautions to observe.

1. List five poor housekeeping practices and explain the danger of each. (6-2-4)

2. List three potential fire hazards in the airframe repair shop. (6-4, 5)

3. An electric motor in the airframe repair shop starts to burn. What type of fire extinguisher should be used? What should be done to prevent personnel from being affected by the fumes produced? (6-6)

4. What is the purpose of the explosimeter? (6-7)

5. What is the normal maximum load you should lift? (6-10)

6. When carrying a load where should it be carried in relation to the body? (6-11)

7. In what way can the hammer, chisel, and punch be an eye injury hazard? (6-14, 17)

8. What are some of the hazards connected with the use of portable power tools? (6-19)

9. When using power machines should they be considered dangerous? (6-22)

10. What safety precautions should be taken when using a power brake? (6-25)

11. What manual governs safety rules and regulations? (6-28)

12. What is meant by "first aid"? (6-32)

13. When should bleeding be stopped by the first aider? (6-35)

14. How should fractures be handled? (6-38)

15. Swimming alone should be ______________________. (6-41)

16. What is one of the first steps to take in aiding an electrical shock victim? (6-42)

17. You discovertthat one of your men is overcome with poisonous vapors. He is still in the bomb bay area, where there is a fuel leak. What first aid procedures should be applied? (6-43, 44)

18. Why is emergency treatment for chemical injury necessary? List the steps which should be followed. (6-43, 44)

19. What are the symptoms of chemical injury? What should be done if the victim is unconscious? (6-43, 44)

20. What is a dislocation? (6-46)

21. What should you do if bitten by an animal? (6-49)

22. Should whiseky be used for snake bites? (6-50)

23. How can you tell if a person needs oxygen? (6-52)

24. When giving mouth-to-mouth artificial resuscitation, how is the victim's air passage kept open? (6-54)

25. Refer to figure 18, AF Form 711, to determine the necessary information to be entered on that form. Select from the items listed below.

On 26 June 1966, AF truck 52-765 owned by the 461st Bomb Wing, collided with a pickup, 66-305, owned by the 629th Field Maintenanee Squadron. The driver of the truck was 25 years old. The dirver of the pickup was 40 years old. Neither of the drivers was injured in the accident.
(6-56; Fig. 18)

26. List the precautions to observe in the handling and storing of chemical solutions. (7-14)

27. List five articles of hazardous wearing apparel that shouldn't be worn around machinery? (7-18)

28. A shipment of aluminum stock arrives. The crating is bad and the sheets of aluminum are loose. What should be done to insure safe handling of this material? (7-22)

29. What are the protective measures required to prevent contact with chemical substances and the inhalation of their fumes? (7-24, 25)

30. What conditions are favorable for the ignition of chemical vapors? (7-26)

Section 8

Objective: To be able to recognize the hazards of making repairs in and around aircraft.

1. What are the hazards of the jet engine intake and exhaust, and the turbine area? (8-3, 4)

2. Given the drawing of an aircraft, identify the engine intake, exhaust, and turbine areas and indicate the minimum safe distances of approach to each. (8-3, 4; Figs. 24, 25)

3. Who will determine the type of ear defenders needed on the flight line? (8-7)

4. High-intensity noise can cause one to become ill. What are the symptoms of noise injury? (8-7)

5. An aircraft has been damaged in combat. The cockpit area is saturated with hydraulic fluid. The aircraft is suspected of radiological contamination. What must be done before the airframe repair specialist can make necessary repairs? (8-8)

6. What damage is possible to aircraft due to failure to use the designated walkways? (8-9)

7. What are the precautions for prevention of accidental firing of seat and canopy ejection systems? (8-11)

8. Why do you, as an airframe repair specialist and/or technician, need to know the location of each ground safety pin for the seat and canopy ejection system on theaaircraft you are repairing? (8-11)

9. Why and under what circumstances is the ejection system unsafe even though the safety pins are correctly installed? (8-11)

10. What are three things that could happen if the airframe repairman should operate cockpit switches, levers, or the control column? (8-12)

11. Cockpit instruments are necessary to enable the pilot to operate his plane correctly. How can you prevent damage to these delicate and sensitive instruments? (8-13)

12. Why is it necessary that you leave your work area in the aircraft clean and free of loose tools and trash? (8-14)

Section 9

Objectives: To be aware of the hazards involved in working with aerospace ground and power equipment? and to define the safety precautions that should be observed.

1. What are three safety precatuions to observe while using portable electric generators? (9-3)

2. What hazards can result from using compressed air to remove dirt and debris from your work area and from your clothes? (9-3)

3. What are four safety precautions to observe when using air compressors? (9-3)

4. A B-52 has been parked pending an airframe repair on the inboard, trailing edge of the right wing. A fuel leak has caused a large puddle of fuel to form under the bomb bay. A portable electric generator is parked downwind about 25 feet from the bomb bay and is being started by the operator. The technician comes out to supervise the repairs. What are five things that he should do? (9-3)

5. Workstands are provided for safe maintenance of aircraft. What are the important things to check for before you use a workstand on upper surfaces of an aircraft? (9-4)

6. The vertical stabilizer on a B-52 aircraft requires repair by the airframe repair shop. The available workstand is not the proper one to use for the job. What would you do if you were the technician supervising the repair? (9-4)

7. List the checks to be made before using a workstand. (9-4)

8. What is the purpose of AFTO Form 35? (9-6)

9. Why should the operator of aerospace ground equipment check AFTO Form 45 before he operates the equipment? (8-8)

10. The airframe repair shop needs to have an aircraft moved so that necessary repairs can be made. The aerospace ground equipment operator who is sent out to do the moving does not have the necessary tow equipment listed on his AFTO Form 35. What should be done in this case? (9-9)

40

MODIFICATIONS

Pages 13-15 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

23. The proper management of equipment and supplies is designed to insure adequate supply levels of materials necessary to support the Air Force mission at all levels of command.

24. Contractor's forms which indicate a serviceable condition are buff in color.

25. Items are obtained for local use from shelf stocks of local vendors by means of local purchase.

26. Authorized inspectors inspect to insure correct tagging of property prior to further storage, shipment, issue and installation.

27. The correct stock number should be entered on the unit or package.

28. All authorized condition tags and labels are prepared by imprinting or by mechanical equipment, if available, and if its installation is authorized.

29. The insignia should be removed from the container because items that are not Hi-Valu are shipped without the insignia.

30. The DD Form 1574 or 1574-1 is used to indicate the serviceability of AF property.

31. You should check the DD Form 1574 or 1574-1 attached to the equipment.

32. DD Form 1577-2 should be used to tag the item. The back side should be used to list missing parts.

33. To indicate the item is unserviceable and is in a condition to render it condemned.

34. The chief inspector is responsible for the removal of authorized tags.

35. The AF quality control inspector is directly responsible for the government quality control of a particular facility or group of facilities. He is to inspect and accept supplies and services for the Government.

36. The supply inspector is responsible for the inspection.

37. False - Not until it has been properly condemned.

Answers for Chapter Review Exercises

CHAPTER 3

Sections 6 and 7

1. (1) Scraps and waste on the floor are a hazard to walking.
   (2) Accumulation of paint-soaked rags can cause a fire.
   (3) Oil or grease on the floor can cause slips and falls.
   (4) Holes in the floor can cause tripping.
   (5) Obstructions in walkways can cause falls, cuts and bruises

2. (1) Smoking around flammable vapor areas.
   (2) Accumulation of oil-soaked rags.
   (3) Poor ventilated areas.

3. Chlorobromonethane or carbon tetrachloride extinguishers; open doors and windows, and turn off the electricity.

4. The explosimeter is used to detect and indicate the presence and intensity of combustible gases.

5. The normal maximum load you sholuld lift is 50 pounds.

6. A load should be carried as close to the body as possible.

7. Flying particles from the tool or material can cause serious eye injury.

8. Some of the hazards connected with the use of portable power tools are electrical shock, burns, cuts, bruises, strains, particles in the eyes, and explosions.

9. Yes. All power machines are classified as being very dangerous.

10. Safety precautions for the power brake are similar to those of the power shear – that is, watch where your hands are and hour helper's hands are before starting the machine.

11 AFM 127-101, *Industrial Safety Accident Prevention Handbook* governs safety rules and regulations.

12. First aid is defined as the immediate and temporary care given the victim of an accident.

13. Bleeding should be stopped as soon as possible.

14. Fractures should be handled carefully to prevent making the injury worse.

15. Avoided.

16. When aiding an electrical shock victim first cut off the power source and get him away from it.

17. Remove the man from the vapor area into fresh air. If he is unconscious, apply artificial respiration and secure medical assistance if possible.

18. Chemicals are toxic and can burn the skin and eyes. Emergency treatment to follow is:

    a. Move the victim into fresh air and use oxygen if necessary.
    b. If clothing is saturated, remove it at once.
    c. Place the victim in deluge shower to dilute the chemical.

19. The symptoms of chemical injury are: drowsiness, headache, listlessness, a sense of wellbeing and buoyance, excitement, disorientation, a reduced level of consciousness, convulsions, and coma. Get the victim into fresh air, give him artificial respiration, and get medical help as soon as possible.

43

20. A dislocation is a more serious type of sprain.

21. If you are bitten by an animal you should go to a doctor.

22. No. Get medical care as soon as possible.

23. By observing a person's color, you can tell if a person needs oxygen – he is pale or blue in color.

24. When giving mouth-to-mouth artificial resuscitation the air passage is kept open by placing the victim's head in the looking-up position.

25. On 26 June 1966, AF truck 52-765, owned by the 461st Bomb Wing, collided with a pickup, 66-305, owned by the 629th Field Maintenance Squadron. Neither of the dirvers was injured.

26. *a.* Store acids in carboys.
    b. Store acids away from possible sources of ignition.
    c. Store paint removers at room temperature.
    d. Pour acid from carboys by use of a tilter or siphon.

27. (1) Ragged or loose-fitting clothing.
    (2) Worn or imporper size gloves.
    (3) Static-producing clothing
    (4) Loose-fitting face mask
    (5) Soft-toe shoes when hard-toe shoes are required.
    (6) Greasy clothing when working around oxygen.
    (7) Watches, rings, and other types of jewelry.
    (8) Neckties.

28. Wear leather gloves, be careful in lifting and letting down, and watch for sharp corners.

29. Wear protective clothing and the proper breathing mask.

30. Concentration of vapors, static sparks, mechanical sparks, and stray electrical sparks.

Section 8

1. Being sucked into the intake, scorched by the exhaust, and injured if the turbine fails.

2. Intake hazardous within 25-foot radius in front of it, exhaust hazardous within 200 feet aft of the exhaust cone, and turbine area hazardous in line with the turbine wheel rotation.

3. The base surgeon.

4. Pain, feeling of fullness, dizziness, ringing of the ears, impariment of mental concentration, nausea, vomiting, and weakness in the knees.

5. The aircraft must be decontaminated.

50

6. Damage to trailing edges, wingtips and control surfaces.

7. Be sure that the ground safety pins and installed; do not have heat around the explosive charges; and have the armament specialist disarm the catapults and ejectors if necessary.

8. To be able to determine if these pins are installed in the firing mechanism.

9. Heat around explosive charges can set off the seat and canopy ejection system.

10. (1) The fuel dump valve may be energized.
    (2) The landing gear may collapse.
    (3) Injury to a flight control mechanic may occur.

11. By being careful not to strike them, damage the wiring or tubing connected to them, not sit on the instrument panel.

12. Tools and debris can cause a malfunction of equipment.

Sectinon 9

1. (1) Do not operate within 50 feet of fueling operations or fuel spillage.
   (2) Position generator upwind of the aircraft.
   (3) Do not operate the generator under aircraft structures.

2. You may get dirt in your eyes or particles may become imbedded in the skin.

3. (1) Keep foreign material from entering the equipment.
   (2) Drain the compressor daily.
   (3) Do not kink the hose.
   (4) Use the high-pressure compressor for high-pressure jobs only.

4. (1) Stop operation at once.
   (2) Check the operator's AFTO Form 35.
   (3) Have the generator parked the required distance upwind.
   (4) Have the spilled fuel washed down.
   (5) Suspend operations until the fuel leak is stopped.

5. See that the stand is in good repair, that it is the proper one for the job, and that it is free from oil and grease.

6. Attempt to secure the proper workstand. If the upper part of the vertical stabilizer is damaged, have it removed so that it may be taken into the shop for repair.

7. *a.* Presence and installation of guardrails that are in good repair.
   b. Proper stand for the job.
   c. Proper operation of the hydraulic lift.
   d. Presence and condition of the safety lock.
   e. Stand must be clean of oil and grease.

8. It is the operator's permit and lists the aerospace ground equipment he is authorized to operate.

9. To know the condition and status of the equipment.

10. Workload control must be contacted for a qualified operator.

46

STOP— 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 PENCIL.

53450 01 27

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp # 1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'T

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a # 1 black lead pencil.

Note: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

53

Multiple Choice

Note: The first three items in this exercise are based on instructions that were included with your course materials. The correctness or incorrectness of your answers to these items will be reflected in your total score. There are no Study Reference Guide subject-area numbers for these first three items.

1. If I tape, staple or multilate my answer sheet; or if I do not cleanly erase when I make changes on the sheet; or if I write over the numbers and symbols along the top margin of the sheet

   a. I will receive a new answer sheet.
   b. my answer sheet will be hand-graded.
   c. I will be required to retake the VRE.
   d. my answer sheet will be unscored or scored incorrectly.

2. So that the electronic scanner can properly score my answer sheet, I must mark my answers with a

   a. ball point or liquid-lead pen.
   b. pen with black ink.
   c. number 1 black lead pencil.
   d. pen with blue ink.

3. The form number of this VRE must match

   a. the form number on the answer sheet.
   b. the number of the Shipping List.
   c. my course volume number.
   d. my course number.

48

MODIFICATIONS

Pages 23 - 25 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Chapter 3

37. (106) An airman has been smoking outside an open window of the chemical storage room where jugs of acid are stored with paint thinner. Whose job is it to see that these fire and explosion hazards are eliminated?

a. The airman's.
b. Yours and the airman's.
c. Using services and operating personnel.
d. Everyone's on the designated Air Force base.

38. (105) Which type of fire extinguisher is *not* recommended for use on electrical fires?

a. Water.
b. Pyrene.
c. Carbon dioxide.
d. Chlorobromomethane.

39. (106) An explosimeter is used to detect

a. TNT.
b. CBM.
c. combustible gases.
d. combustible solids.

40. (106) The normal maximum load for an individual to lift safely is

a. 25 pounds.
b. 50 pounds.
c. 75 pounds.
d. 100 pounds.

41. (106) In the interest of safety, hammer handles should never be used to pound metal because this

a. weakens the handle.
b. misshapes the metal truck.
c. corrodes the metal inserts.
d. deteriorates the striking face.

42. (106) To answer questions regarding safety instructions and regulations, consult

a. H6-1.
b. AFM 67-1;
c. AFM 127-1010.
d. AFM 205-1.

43. (107) The first aid treatment suggested for a scuff burn is to cleanse the wound with

a. alcohol.
b. hot water.
c. cold water.
d. water at room temperature.

44. (107) Choose the correct statement about first aid treatment of burns.

a. First aid treatments of burns caused by very high ahd very low temperatures are identical.
b. The patient should not be given liquids to drink.
c. Fabric stuck to burned areas should be removed.
d. Severe burns should be lubricated with ointment.

45. (107) The proper first aid treatment for a sprained ankle is to

a. keep the joint limber by moving it.
b. use an ice pack to retard swelling.
c. apply hot compresses.
d. keep the leg flat on the ground.

46. (107) Approximately how many times per minute should the rhythmic cycle for artificial respiration be repeated for an adult?

a. 8.
b. 12.
c. 16.
d. 20.

47. (107) a. Airman James C. Day was on a B-4 maintenance stand aft of the wing section of a B-52.
b. He was replacing several popped rivets when he became overbalanced and fell to the ramp.
c. He had failed to install the guard rails.
d. As the result, he received several bruises and abrasions.
e. He was hospitalized for 2 weeks.
f. Airman Day was from the 2025th Civil Engineer Group, airframe repair shop.
g. The aircraft was assigned to the 3021st Bomb Group at Mather AFB, California
h. The aircraft crew was asleep in the V.O.B.O.Q. at the time of the accident.
i. Airman Day was charged with neglect to apply recognized safety measures.

From the above statements of a flightline accident, which items of information are not needed on AF Form 711?

a. a and b.
b. c, d, and e.
c. f and g.
d. h and i.

48. (107) An Accident/incident Report is authenticated by the

a. base commander.
b. individuals involved in the accident.
c. immediate superior of the individual involved in the accident.
d. president of the investigating board.

49. (108) Which statement concerning a vapor is *not* correct?

a. A vapor can be a gas which is normally a liquid.
b. A vapor can be a gas emitted by a solid.
c. A vapor is usually lighter than air.
d. The lightness of a vapor is controlled by the density of its molecules.

50. (108) Gases and vapors are grouped according to their

a. color. c
b. density.
c. effect on the body.
d. degree of danger.

51. (108) How can personnel be protected from irritant gases and vapors which are anesthetic and toxic in nature?

a. Authorized persons will mix only authorized substances and wear protective clothing.
b. Unauthorized persons can mix authorized mixtures as long as they follow the directions.
c. Authorized persons can mix unauthorized substances as long as they follow the directions.
d. Authorized persons can mix substances as long as they do so in the authorized and designated area.

52. (108) Particles resulting from the condensation of substances which have been heated or burned are called

a. vapors.
b. gases.
c. fumes.
d. napthas.

53. (108) When do most serious accidents involving paint removers occur?

a. During storage.
b. When opening the container.
c. During fires.
d. After mixing paints.

54. (108) When working around oxygen or oxygen systems, which of the following items of wearing apparel is potentially the most dangerous to the wearer?

a. Soft-toe shoes.
b. Rings and watches.
c. Loose-fitting clothing.
d. Dirty and greasy clothing.

55. (108) A shipment of sheet aluminum arrived at the airframe repair shop. It had been shipped in an open-bed truck and was wet. The forklift was out for repair and the metal had to be removed from the crate and dried. After it has been dried, what has to be done to prevent damage to the metal?

a. Store in a cool, dry place.
b. Store in shelves.
c. Store in shelves with paper between the sheets.
d. Store in shelves and separated according to size.

56. (109) Use figures 23 and 24 of the text for this question. Locate the hazardous areas and indicate the safe distances of approach to them.

a. Intake 25 feet, exhaust 200 feet, turbine rotation line.
b. Intake 20 feet, exhaust 200 feet, turbine rotation line.
c. Intake 25 feet, exhaust 150 feet, turbine rotation line.
d. Intake 25 feet, exhuast 100 feet, turibne rotation line.

57. (109) Which work area would require the most efficient ear defenders?

a. The airframe repair shop.
b. The ramp area several hundred yards away from operating aircraft.
c. The ramp area near the flightline with helicopter and reciprocating aircraft operation.
d. The ramp area near the flightline with nothing but jet aircraft operation and engine runnup.

58. (109) One symptom of high-intensity noise damage is

a. a swelling of the face.
b. blood-shot eyes.
c. a high temperature.
d. nausea.

59. (109) It is necessary that the airframe repair shop replace an 18-inch-square sheet of aluminum in the cockpit area. The aircraft is suspected of having been exposed to radioactivity. What must be done before the repairs can be made?

a. Put up warning signs.
b. The aircraft must be decontaminated.
c. Check the aircraft for hazardous vapors with an explosimeter.
d. The aircraft must have AFTO Form 9c posted on each side of the cockpit.

60. (109) The airframe repair specialist is not to operate the control column because

a. the fuel tank may be energized.
b. it contains an explosive charge.
c. a mechanic's hand could be seriously injured.
d. the landing gear might collapse.

61. (109) Operating power units should be what *minimum* distance from fueling operations?

a. 40 feet.	c. 60 feet.
b. 50 feet.	d. 75 feet.

62. (109) What is the primary purpose of AFTO From 35?

a. To identify the AGE operator.
b. To identify authorized AGE for a shop.
c. To identify AGE the operator is authorized to operate.
d. To serve as a guide for pre-operation inspection of AGE.

63. (109) The airframe repair shop must have the use of a piece of aerospace ground equipment The operator who is sent out to operate the equipment doesn't have the item listed on his operator's permit. What is the proper procedure for the supervisor to follow?

a. Give the operator his permission to operate the item.
b. Contact workload control for the loan of an authorized operator.
c. Contact the training control section for permission to operate the equipment.
d. Postpone the work until the operator can be trained and authorized to operate AGE.

54

53450 02 0968

CDC 53450

AIRFRAME REPAIRMAN/TECHNICIAN

(AFSCs 53450 and 53470)

Volume 2

Fundamentals of Metalworking

2-3

Extension Course Institute

Air University

61

Preface

IN THIS volume of the airframe repairman course, the subject matter consists of the essentials—the backbone of our career field—in other words, the composition and the processing of aluminum, titanium, steels, and magnesium to obtain the desired end product.

Included in this discussion will be materials identification, metalmarking, composition, physical properties, working characteristics, and how to change the working characteristics through heat-treatment. Also included are the differences in cutting, drilling, grinding, and forming of these metals. In addition, we cover, at some length, corrosion control and prevention to assist you in prolonging the life of our materials and weapons systems.

Because of the time lapse between the achievement of the 3, 5, and 7 levels of this career field, a comprehensive summary review of the knowledge obtained in the basic airframe course is included. The necessity for retention of the knowledge previously obtained in the use of the layout tools, measurement equipment, handtools, and power equipment is such that these items could not be ignored.

You will study the use and care of many powered and nonpowered tools, some of which you may not have access to while studying this course; but the working knowledges are essential to you for safe, economical, and reliable work performance on the job.

The number which appears on the figures in this volume (for example 530-3484) represents the preparing agency's illustration file number.

Included in this volume is a foldout. Whenever you are referred to it, turn to the back of the volume and study it.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TSOC), Chanute AFB IL 61866.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, Alabama 36114, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 45 hours (15 points).

57

Contents

Page

Preface iii

Chapter

1 AIRCRAFT METALS 1

2 CORROSION CONTROL OF METALS 63

3 METAL CUTTING 93

4 HAND AND MACHINE FORMING OF METALS 119

5 Shop Mathematics

63

CHAPTER 1

Aircraft Metals

IF A PART required exceptional strength to do a particular job and a soft metal was selected to do that job, what could be the results? Picture yourself at a picnic. Out of the sky came tumbling the remains of an aircraft; 200,000 pounds of metal—men, women, and children covered with all that material. Could this be the result of an aircraft being put together by people that did not understand and take into consideration the many factors involved in metals and their properties? Maybe it hasn't happened in the past, but unless *you* know what *you* are doing with those metals, it could happen in the future. This chapter contains information you need to identify and select the proper material for a specific repair and, through this knowledge, to reduce the possibility of your making an improper selection. It deals with the source of material, substitution, and interchangeability of metals that are required knowledge for you to go to the 5 ~~and 7 level~~. You will study the uses, physical properties, working characteristics, and differences between aluminum, titanium, steel, and magnesium. You will also find out how to requisition and store material and how to inspect and compare properly repaired parts with poorly repaired parts made of these four metals.

1. Aluminum

1-1. Although aluminum is used on a day-by-day basis within our career field, the individual using aluminum generally knows very little about this metal. Aluminum is one of the most abundant metals of the earth. About one-twelfth of the earth's crust contains aluminum—almost twice as much as the earth's iron content. Aluminum is never found as a free material in nature, although most rocks and clay contain some amounts of aluminum. Because of the extensive chemical processes, it is impractical to extract aluminum unless the ore contains a high precentage of alumina (aluminum oxide). Ores containing these high amounts of alumina are called "bauxites" for the French town of Les Baux where early discovery of this material was made. Bauxites is the princple source of metallic aluminum. When found in nature, it is claylike and its color ranges from white to reddish brown. In a series of steps, crushed ore is transformed into alumina for the electrolytic reduction cells which yield metallic aluminum.

1-2. **Types.** Many types and shapes of metallic aluminum are used in industry today. Powders have a wide range of uses such as paint pigment, catalysts, desiccants, pharmaceuticals, and even face cream for ladies. Metal aluminum is one of the nonferrous metals. Nonferrous refers to all metals which have elements other than iron as their base or principal constituent. This group includes such metals as aluminum, titanium, copper, and magnesium.

1-3. **Properties of Metals.** Before we discuss the individual properties of aluminum, perhaps we should recall the terms associated with metals in general and what the terms mean in individual characteristics. Of primary concern in aircraft maintenance are such general properties of metals and their alloys as hardness, malleability, ductility, elasticity, toughness, density, brittleness, fusibility, conductivity, contraction, and expansion.

1-4. *Hardness.* Hardness is the ability of a metal to resist abrasion, penetration, cutting action, or permanent distortion. Hardness may be increased by working the metal and, in the case of steel and certain aluminum alloys, by heat-treatment and cold-working. Structural parts are often formed from metals in their soft state and are then heat-treated to harden them so that the finished shape will be retained. Hardness and strength are closely associated properties of metals.

1-5. *Malleability.* A metal which can be hammered, rolled, or pressed into various shapes without cracking, breaking, or other detrimental effects is said to be malleable. This property is necessary in sheet metal that is worked into curved shapes such as cowlings, fairings, and wing tips. Copper is an example of a malleable metal.

1-6. *Ductility.* Ductility is the property of a metal which permits it to be permanently drawn, bent, or twisted into various shapes without breaking. This property is essential for metals used in making wire and tubing. Ductile metals are greatly preferred for aircraft use because of their ease of forming and resistance to failure under shock loads. For this reason, aluminum alloys are used for cowl rings, fuselage and wing skin, and formed or extruded parts such as ribs, spars, and bulkheads. Chrome molybdenum steel is also easily formed into desired shapes. Ductility is similar to malleability.

1-7. *Elasticity.* Elasticity is that property which enables a metal to return to its original shape when a force which causes the change of shape is removed. This property is extremely valuable because it would be highly undesirable to have a part permanently distorted after an applied load was removed. Each metal has a point known as the elastic limit beyond which it cannot be loaded without causing permanent distortion. In aircraft construction, members and parts are so designed that the maximum loads to which they are subjected will never stress them beyond their elastic limits. This desirable property is exemplified in spring steel.

1-8. *Toughness.* A material which possesses toughness will withstand tearing or shearing and may be stretched or otherwise deformed without breaking. Toughness is a desirable property in aircraft metals.

1-9. *Density.* Density is the weight of a unit volume of a material. In aircraft work, the actual weight of a material per cubic inch is preferred since this figure can be used in determining the weight of a part before actual manufacture. Density is an important consideration when choosing a material to be used in the design of a part in order to maintain the proper weight and balance of aircraft.

1-10. *Brittleness.* Brittleness is the property of a metal which allows little bending or deformation without shattering. A brittle metal is apt to break or crack without change of shape. Because structural metals are often subjected to shock loads, brittleness is not a very desirable property. Cast iron or cast aluminum and very hard steel are brittle metals.

1-11. *Fusibility.* Fusibility is the ability of a metal to become liquid by the application of heat. Metals are fused in welding. Steels fuse at approximately 2500° Fahrenheit, and aluminum alloys at approximately 1100° Fahrenheit.

1-12. *Conductivity.* Conductivity is the property which enables a metal to carry heat or electricity. The heat conductivity of a metal is especially important in welding because it governs the amount of heat that will be required for proper fusion. Conductivity of the metal, to a certain extent, determines the type of jig to be used to control expansion and contraction. In aircraft, electrical conductivity must also be considered in conjunction with bonding, to eliminate radio interference. Metals vary in their capacity to conduct heat. Copper, for instance, has a relatively high rate of heat conductivity and is a good electrical conductor.

1-13. *Contraction and expansion.* Contraction and expansion are reactions produced in metals as the result of heating or cooling. A high degree of heat applied to a metal will cause it to expand or become larger. Cooling hot metal will shrink or contact it. Contraction and expansion affect the design of welding jigs, castings, and tolerances necessary for hot-rolled material.

1-14. **Selection Factors.** The selection of proper materials is a primary consideration in the development of an airframe and in the proper maintenance and repair of aircraft. Keeping in mind the general properties of metals, we can now consider the specific requirements which metals must meet to be suitable for aircraft purposes.

1-15. Strength, weight, reliability—these three factors determine the requirements to be met by any material used in airframe construction and repair. Airframes must be strong and yet as light in weight as possible. There are very definite limits to which increases in strength can be accompanied by increases in weight. An aircraft so heavy that it could not support over a few hundred pounds of additional weight would be of little use.

1-16. All metals, in addition to having a good strength-to-weight ratio, must be thoroughly reliable, thus minimizing the possibility of dangerous and unexpected failures. In addition to these general properties, the material selected for a definite application must possess specific qualities suitable for the purpose. When you are determining the most suitable material for a particular aircraft construction or repair job, consider the qualities discussed below.

1-17. *Strength.* The material must possess the strength required by the demands of dimensions, weight, and use. There are five basic stresses which metals may be required to withstand. These are tension, compression, shear, bending, and torsion. Let us examine them separately.

1-18. Tensile strength (tension) of a material is its resistance to a force which tends to pull it apart. Tensile strength is measured in pounds per square inch (psi) and is calculated by dividing the load, in pounds, required to pull the material apart by its cross-sectional area, in square inches.

1-19. Compression strength of a material is its resistance to a crushing force, which is the opposite of tensile strength. Compression strength is also measured in pounds per square inch.

1-20. Shear strength is the ability of a material to withstand shear.. When a piece of metal is cut, the material is subjected (as it comes in contact with the cutting edge) to a force known as shear. Shear is the tendency of the part or parallel members to slide in opposite directions. It is like placing a cord or thread between the blades of a pair of scissors. The shear strength is the shear force in pounds per square inch at which a material fails. It is the load divided by the shear area.

1-21. Bending strength of material is the resistance it offers bending. Bending may be described as the deflection or curving of a member due to forces acting upon it.

1-22. Torsional (torsion) strength is the resistance to twisting. Such twisting occurs when a member is fixed at one end and twisted at the other.

1-23. *Weight.* The relation between the strength of a material and its weight per cubic inch is known as the strength/weight ratio. This ratio forms the basis for comparing the desirability of various materials for use in airframe construction and repair. Neither strength nor weight alone can be used as a means of true comparison. In some applications such as the skin of monocoque structures, thickness is more important than strength. In this instance, the material with the lightest weight for a given thickness or gage is best. Thickness or bulk is necessary to prevent buckling or damage caused by careless handling.

1-24. *Corrosive properties.* Corrosion is the eating away or pitting of the surface or the internal structure of metals. Because of the thin sections and the safety factors used in aircraft design and construction, it would be dangerous to select a material subject to severe corrosion. Corrosion is caused by the exposure of metals to fumes, water, acids, or moist air, especially moist salt air. Corrosion can be reduced or prevented by using better grades of base metals; by coating the surface with a thin coat of paint, tin, chromium, or cadmium; or by the electrochemical process called anodizing. Details concerning corrosion, its causes, and prevention will be discussed in more detail in Chapter 2 of this volume.

1-25. *Workability.* Another significant factor to consider in maintenance and repair is the ability of a material to be formed, bent, or machined to required shapes. The hardening of metals by cold-working or forming is termed work-hardening. If a piece of metal is formed (shaped or bent) while cold, it is said to be cold-worked. Nearly all of the work an airframe repairman does on metal is cold-work. While this is convenient, it causes the metal to become harder and more brittle.

1-26. If the metal is cold-worked too much, that is if it is bent back and forth or hammered at the same place too often, it will crack or break. Usually the more malleable and ductile a metal is, the more cold-working it can stand. Any process which involves controlling heating and cooling of metals to develop certain desirable characteristics (such as hardness, softness, ductility, tensile strength, or refined grain structure) is called heat-treatment or heat-treating. With steels the term "heat-treating" has a broad meaning and includes such processes as annealing, normalizing, hardening, and tempering.

1-27. In the heat-treatment of aluminum alloys only two processes are included: the hardening and toughening process, and the softening process. The hardening and toughening process is called heat-treating, and the softening process is called annealing. Therefore, when you speak of heat-treating, you must first consider the material with which you are working. If it is steel, the term may mean one of several processes during which heat is applied; but if the metal is aluminum alloy, the term can only mean hardening.

1-28. *Shock and fatigue resistance.* Aircraft metals are subjected to both shock and fatigue (vibrational) stresses. If the fatigue limit is reached or exceeded, fatigue occurs in materials that are exposed to frequent reversals of loading or repeatedly applied loads. Repeated vibration or bending will ultimately cause a minute crack to occur at the weakest point. As vibration or bending continues, the crack lengthens until complete failure of the part results. This is termed shock or fatigue failure. Resistance to this condition is known as shock or fatigue resistance. It is essential that materials used for critical parts be resistant to these stresses.

1-29. *Ease of attachment.* Joining metals structurally by welding, brazing, or soldering, or by such mechanical means as riveting or bolting, is a tremendous help in design and fabrication. When all other properties are equal, material that can be welded has the advantage.

1-30. Keeping in mind the terms we have discussed covering metal properties and characteristics in general, let us now return to aluminum and elaborate on why this metal is one of the most desirable of metals for general use on aircraft. Also we will discuss how it is identified, requisitioned, cared for, and used.

1-31. **Aluminum.** Commercially pure aluminum is a white lustrous metal which stands second in the scale of malleability, sixth in ductility, and ranks high in its resistance to corrosion. Commercially pure aluminum has a tensile strength of about 13,000 pounds per square inch, but by rolling or other cold-working processes its strength can be almost doubled. By alloying with other metals and by using heat-treating processes, the tensile strength may be raised to as high as 100,000 pounds per square inch, or within the range of structural steel. Aluminum weighs far less than most metals. In the alloy form it weighs about 0.1 pound per cubic inch. This is about one-third the weight of iron at 0.28 pounds and copper at 0.32. It is slightly heavier than magnesium at 0.066 and somewhat lighter than titanium at 0.163 pounds.

1-32. Aluminum combined with various percentages of other metals (generally copper, manganese, magnesium, and chromium) forms alloys which are used in aircraft construction. Aluminum alloys in which the principal alloying ingredients are either manganese, magnesium, chromium, or magnesium and silicon show little attack in corrosive environments. Alloys in which substantial percentages of copper are used are more susceptible to corrosive action. The total percentage of alloying elements is seldom more than 6 or 7 percent in the wrought alloys.

1-33. Aluminum is one of the most widely used metals in modern aircraft construction. It is vital to the aviation industry because of its high strength-to-weight ratio and its comparative ease of fabrication. The outstanding characteristic of aluminum is its light weight. Aluminum melts at the comparatively low temperature of 1250° F. It is nonmagnetic and is an excellent conductor.

1-34. Most aluminum alloys, although strong, are easily worked because they are malleable and ductile. They may be rolled into sheets as thin as 0.0017 inch or drawn into wire 0.004 inch in diameter. Most aluminum alloy sheet stock used in aircraft construction ranges from 0.016 to 0.096 inch in thickness; however, sheet stock which may be as thick as 0.356 inch is used on some of the larger aircraft.

1-35. One disadvantage of aluminum is the difficulty of making reliable soldered joints. Oxidation of the surface of the heated metal prevents soft solder from adhering to the material; therefore, to produce good joints when working with aluminum alloys, a riveting process is used.

1-36. The various types of aluminum may be divided into two general classes: the casting alloys (those suitable for casting in sand, permanent mold, and die castings), and wrought alloys (those which may be shaped by rollings, drawing, or forging). Of these two, the wrought alloys are the most widely used in aircraft construction for stringers, bulkheads, skin, rivets, and extruded sections.

1-37. *Cast.* Cast aluminum alloys are divided into two groups. In one, the physical properties are determined by the elements added and the properties cannot be changed after the metal is cast. In the other, the elements added make it possible to heat-treat the castings to improve their mechanical properties and dimensional stability. High strength, together with good ductility, can be obtained by selection of suitable composition and by heat-treatment.

1-38. The casting alloys are identified by a letter preceding the alloy number. When a letter precedes a number, it indicates a slight variation in the composition of the original alloy. This variation is made simply to impart some desirable quality. In casting alloy 214, for example, the addition of zinc to increase the pouring qualities is designated by the letter A in front of the number, thus the designation A214.

1-39. When castings have been heat-treated, the heat-treatment and the composition of the castings are indicated by the letter T following the alloying number. An example of this is the sand casting alloy 355 which has several different compositions and tempers, and is designated by 355-T6, 355-T51, and A355-T51.

1-40. Aluminum alloy castings are produced by one of three basic methods: sand mold, permanent mold, or die casting. In casting aluminum, it must be remembered that in most cases different types of alloys must be used for different types of casting. Sand castings and die castings require different types than those used in permanent molds.

1-41. Sand and permanent mold castings are produced by pouring molten metal into a previously prepared mold, after which you allow the metal to solidify or freeze and then remove the part. If the mold is made of sand, the part is a sand casting; if it is a metallic mold, usually cast iron, the part is a permanent mold casting. The metal flows into the mold under the force of gravity alone.

1-42. The two principal types of sand casting alloys are numbered 112 and 212. Little difference exists between the two metals from the mechanical properties standpoint, since both are adaptable to a wide range of products.

1-43. The permanent mold process is a later development of the sand casting process. The major difference is the material from which the molds are made. The advantage of this process is that there are fewer openings (call porosity) in the finished product than in sand castings. The sand and binder, which is mixed with the sand to hold it together, give off a certain amount of gas in the sand casting which causes porosity. Permanent mold castings are used to obtain higher mechanical properties, better surfaces, or more accurate dimensions. There are two specific types of permanent mold castings: the permanent mold with metal cores, and the semipermanent types containing sand cores. Because finer grain structure is produced in alloys subjected to the rapid cooling of metal molds, they are far superior to the sand type castings. Alloy 122, A132, and 142 are commonly used in permanent mold castings. These castings are primarily used in internal combustion engines.

1-44. Die castings used in aircraft are usually aluminum or magnesium alloy. If weight is of primary importance, magnesium alloy is used since it is lighter than aluminum. Since aluminum alloy is a little stronger than most magnesium alloys, it is frequently specified. A die casting is produced by forcing molten metal under pressure into a metallic die and allowing it to solidify. The die is opened and the part removed. The basic difference between permanent mold casting and die casting is that in the permanent mold process the metal flows into the die under gravity flow only. In the die casting operation, the metal is forced under great pressure. Die castings are used where relatively large production of a given part is involved. Remember, any shape which can be forged can be cast. This background of castings is necessary so that you will have an understanding of the nature of the cast parts encountered in the process of repairing parts. The primary type of material most encountered by the airframe repairman is the wrought form.

1-45. *Wrought.* Most aluminum alloys used for wrought products contain less than 7 percent of alloying elements. By the regulation of the amount and type of elements added, the properties of aluminum can be enhanced and the working characteristics improved. Special compositions have been developed for particular fabrication such as forging and extrusion.

1-46. As with casting alloys, wrought alloys are produced in both heat-treatable and nonheat-treatable types. The principal wrought forms of alloyed aluminum are plate and sheet, foil, extruded shapes, tube, bar, wire, and forging.

1-47. Nonheat-treatable alloys are those in which the mechanical properties are determined by the amount of cold-working introduced after the final annealing operation. The mechanical properties obtained by cold-working are destroyed by any subsequent heating and cannot be restored except by additional cold-working, which is not always possible. The "full hard" temper is produced by the maximum amount of cold-work that is commercially practicable. Metal in the "as fabricated" condition is produced from the ingot without any subsequent controlled amount of cold-working or thermal treatment. There is, consequently, a variable amount of strain-hardening, depending upon the thickness of the section.

1-48. For heat-treatable aluminum alloys, the desired mechanical properties are obtained by heating the alloys to a suitable temperature, holding the alloys at that temperature long enough to allow the alloying constituent to enter into solid solution, and then quenching to hold the constituent in solution. The metal is left in a supersaturated unstable state and is then age-hardened either by natural aging at room temperature or by artificial aging at some elevated temperature.

1-49. **Four-Digit Index System.** Wrought aluminum and wrought aluminum alloys are designated by a four-digit index system. The system is divided into three distinct groups: 1xxx group, 2xxx through 8xxx group, and 9xxx group (which is unused at present).

1-50. In the 1xxx group, the first number indicates that the alloy contains at least 99 percent pure aluminum. The second digit of the group indicates controls over the impurities contained in the alloy. Should the second number be zero, it would indicate no special control over individual impurities. Digits 1 through 9, however, when assigned consecutively as needed for the second number in this group, indicate the number of controls over individual impurities in the metal.

1-51. The last two digits of the 1xxx group are used to indicate the hundredths of 1 percent above the original 99 percent designated by the first digit. Thus, if the last two digits were 30, the alloy would contain 99 percent plus .30 percent of pure aluminum, or a total of 99.30 percent pure aluminum. Examples of alloys in this group are:

1100	99.00 percent pure aluminum with one control over individual impurties
1130	99.30 percent pure aluminum with one control over individual impurities
1275	99.75 percent pure aluminum with two controls over individual impurities

1-52. In the 2xxx through 8xxx groups, the first digit indicates the major alloying element used in the formation of the alloy as follows:

2xxx—copper
3xxx—manganese
4xxx—silicon

5xxx—magnesium
6xxx—magnesium and silicon
7xxx—zinc
8xxx—other elements

1-53. In the 2xxx through 8xxx alloy groups, the last two of the four digits in the designation serve only to identify the different alloys in the group. Generally, these digits are the same as those formerly used to designate the same alloy. Thus, 2014 was formerly 14S, 3003 was 3S, and 7075 was 75S. (Consult the Aluminum Alloy Designation Conversion Table in TO 42D1-1-3 for further information.) For new alloys, the last two digits are assigned consecutively beginning with xx01.

1-54. In the 2xxx through 8xxx alloy groups, the second digit in the alloy designation indicates alloy modifications. If the second digit is zero, it indicates the original alloy. The digits 1 through 9 indicate alloy modifications. In the former index system, letters were used to designate alloy modifications. These were assigned consecutively, beginning with the letter A. Thus, 17S is now 2107, A17S is 2117, 18S is 2018, and B18S is 2218.

1-55. **Temper Designations.** Where required, the temper designation follows the alloy designation and is separated from it by a dash; i.e., 7075–T6, 2024–T4, etc. The temper designation consists of a letter indicating the basic temper which may be more specifically defined by the addition of one or more digits. These designations are as follows:

–F	As fabricated	
–O	Annealed, recrystallized (wrought products only)	
–H	Strain-hardened	
	–H1	(plus one or more digits) Strain-hardened only
	–H2	(plus one or more digits) Strain-hardened and partially annealed
	–H3	(plus one or more digits) Strain-hardened and stabilized
–W	Solution heat-treated unstable temper	
–T	Treated to produce stable tempers other than –F, –O, or –H	
	–T2	Annealed (cast products only)
	–T3	Solution heat-treated and then cold-worked
	–T4	Solution heat-treated
	–T5	Artificially aged only
	–T6	Solution heat-treated and then artificially aged
	–T7	Solution heat-treated and then stabilized
	–T8	Solution heat-treated, cold-worked, and then artificially aged
	–T9	Solution heat-treated, artificially aged, and then cold-worked
	–T10	Artificially aged and then cold-worked

1-56. In the wrought form, commercially pure aluminum is known as 1100. It has a high degree of resistance to corrosion and is easily formed into intricate shapes. It is relatively low in strength, however, and does not have the strength required for structural aircraft parts. It is not heat-treatable, and higher strengths are generally obtained by the process of alloying. The resulting alloys are less easily formed and, with some exceptions, have lower resistance to corrosion than 1100.

1-57. Alloying is not the only method of increasing the strength of aluminum. Like other materials, aluminum becomes stronger and harder as it is rolled, formed, or otherwise cold-worked. Since the hardness depends on the amount of cold-working done, 1100 and several other wrought alloys are available in a variety of strain-hardened tempers. The soft or annealed condition is designated 0 and the full hard H18, with the intermediate tempers from H12 to H16.

1-58. The most widely used alloys in aircraft construction are hardened by heat-treating rather than cold-work. These alloys are designated by a different set of symbols: –T4 and W indicate solution heat-treatment and quenched but not aged, and –T6 indicates an alloy in the heat-treated hardened condition.

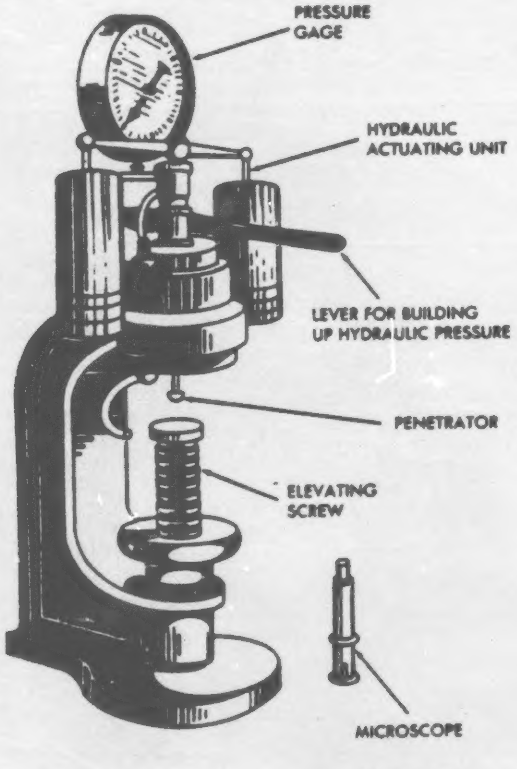
1-59. If the material is strain-hardened, it is said to be in the H condition.

1-60. **Alclad and Pureclad.** The terms "Alclad" and "Pureclad" are used to designate sheets that consist of an aluminum core coated with a layer of pure aluminum to a depth of approximately 5½ percent on each side. Aluminum coated in this manner affords a dual protection for the core by (1) preventing contact with any corrosive agents and (2) preventing any attack from scratching or other abrasion protecting the core electrolytically. Do not be misled by thinking that the pure aluminum coating completely prevents the core from being damaged. Careless handling and sloppy workmanship will damage a piece of clad aluminum beyond aircraft usability. Workmanship dealing with this metal is covered later in this chapter.

1-61. **Methods of Identifying Materials.** The Air Force requires that all aluminum-base alloys be marked with the specification number or code marking (TO 42D–1–3) on approximately every square foot of material. If the material is not marked, the material is required to be identified and remarked prior to use or storage. There are three primary ways of identifying aluminum materials. These are chemical, hardness or tensile testing, and specification marking or color coding.

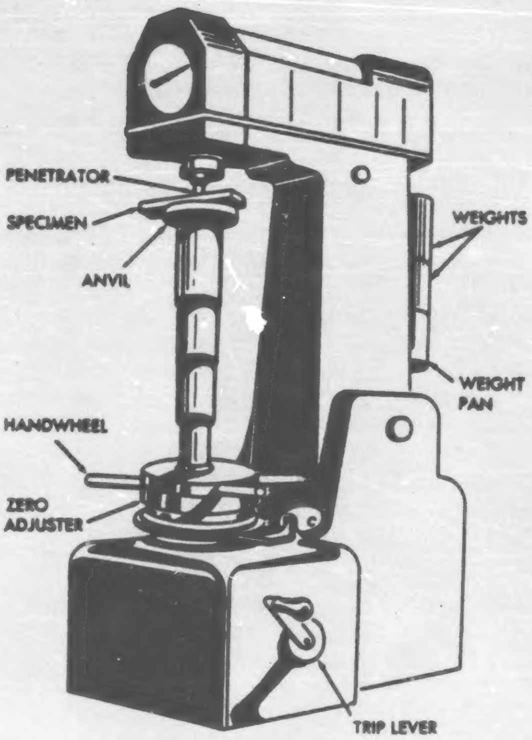
1-62. *Chemical.* If for any reason the identification marking is not on the material, it is possible to separate the heat-treatable alloys from the non-heat-treatable by immersing a sample of the material in a 10 percent solution of caustic soda (sodium hydroxide). The heat-treatable alloys will turn black due to the copper content of the alloy, whereas the others will remain bright. In the case of clad material, the surface will remain bright but there will be a dark area in the middle when viewed from the edge.

1-63. *Hardness testing method.* Hardness testing is a factor in the determination of the results of heat-treatment as well as the condition of the metal before heat-treatment. There are two standard methods of hardness testing, the Brinell and the Rockwell, which require machines.



53450-2-1-52

Figure 1. Brinell hardness tester.



53450-2-1-50

Figure 2. Rockwell hardness tester.

1-64. The Brinell hardness test consists of pressing a hardened steel ball into a flat surface of the metal being tested by the application of a measured pressure. The impression made by the ball is measured by means of a microscope with a micrometer eyepiece. The Brinell number is obtained by dividing the load in kilograms by the area of the spherical impression made by the ball, measured in square millimeters. The Brinell tester is shown in figure 1.

1-65. The Rockwell hardness test consists of the measurement of the difference between a minor and major load applied to a diamond penetrator or hardened steel ball. In all tests, a minor load of 10 kilograms is first applied in order to seat the penetrator in the surface of the metal being tested. The actual penetration is then produced by applying a major load. When using the diamond cone penetrator, this major load is 250 kilograms; but when a one-sixteenth steel ball is used, the load is reduced to 100 kilograms.

1-66. An indication of the application of the major load may be observed by watching the dial indicator attached to the equipment. After the pointer comes to rest, this major load is released, leaving the minor load still applied. As Rockwell hardness numbers are based on the difference between the depths of penetration at major and minor loads, it will be evident that the greater this difference the less the hardness number and the softer the material. When the major load is released, this difference is automatically registered by the reversed scale on the indicator dial which reads the Rockwell hardness number. Note the Rockwell tester in figure 2.

1-67. The several tempers which aluminum alloys contain vary in tensile strength and hardness and can only be identified by means of tensile test or hardness tests. Table 1 gives the Rockwell hardness values for the material used by the Air Force. Use the Rockwell hardness test only when equipment is not available for making a tensile test. In the case of thin sheets, make certain that the tensile results represent the hardness of the material being tested and not the material used in the support.

1-68. The values for heat-treated materials 2017–T4 and 2024–T4 represent material that has been quenched and aged at room temperature for not less than 4 days, or in the case of 2014–T6, for 8 hours at 340° to 360° Fahrenheit.

1-69. Rockwell hardness tests may be used to distinguish between annealed and cold-worked or heat-treated material, but not for alloy identification. The values given in table 1 are obtained with the one-eighth ball and 100-kilogram load, reading the red figures on the dial. Hardness readings are not reliable on materials less than one-sixty-fourth (0.015) of an inch in thickness.

TABLE 1

ROCKWELL HARDNESS TABLE

Commercial Designation	Temper	Rockwell E*
1100–0	Soft	5 Maximum
1100–H14	Half-hard	10 Minimum
2014–0	Annealed	73 Maximum
2014–T6	Heat-treated and artificially aged	100 Minimum
2017–0	Annealed	70 Maximum
2017–T4	Heat-treated	90 Minimum
2024–0	Annealed	70 Maximum
2024–T4	Heat-treated	95 Minimum
5052–0	Soft	65 Maximum
5052–H14	Half-hard	70 Minimum
7075–T6	Heat-treated and artificially aged	105 Minimum
7075–0	Annealed	80 Maximum
7178–T6	Heat-treated and artificially aged	105 Minimum
7178–0	Annealed	80 Maximum
195	Heat-treated	65 Minimum

*Rockwell E—Red scale reading, 100 kilogram load, ⅛ inch ball.

53450-2-2-T1

1-70. An accurate direct test cannot be obtained with the Rockwell hardness tester on clad aluminum alloy sheets. If the hardness value of the base metal is desired, the pure aluminum coating must be removed from the area prior to testing.

1-71. *Color coding.* The identification of small sizes of bars, tubing, and wire by specification number is impractical. A code marking consisting of painted stripes has been established. The identification markings as specified in TO 42D–1–3 are as follows:

Number	*Letter*	*Color*
1	F	Blue
2	H	Green
3	O	Olive Drab
4	T	Yellow
5	W	Orange
6	A	Red
7	B	Maroon
8	C	White
9	D	Gray
0	S	Black
	*N	Gold
	**Q	Silver

1-72. Tubes, bar stock, etc. are marked on each end 2 inches from the end. In the case of the numbering system, there may be either dots or stripes to identify the material content. The temper condition may be marked or it may be omitted. If the marking on the material consists of only four colored stripes or dots, the temper condition has been omitted and only the material composition is shown.

1-73. Using the preceding code, aluminum alloy 2024 is marked green, black, green, yellow, starting 2 inches from the end. If the material is aluminum alloy 7075 and the condition –T6 is shown on the material, it is marked maroon, black, maroon, orange, a 1-inch space, and then yellow, red.

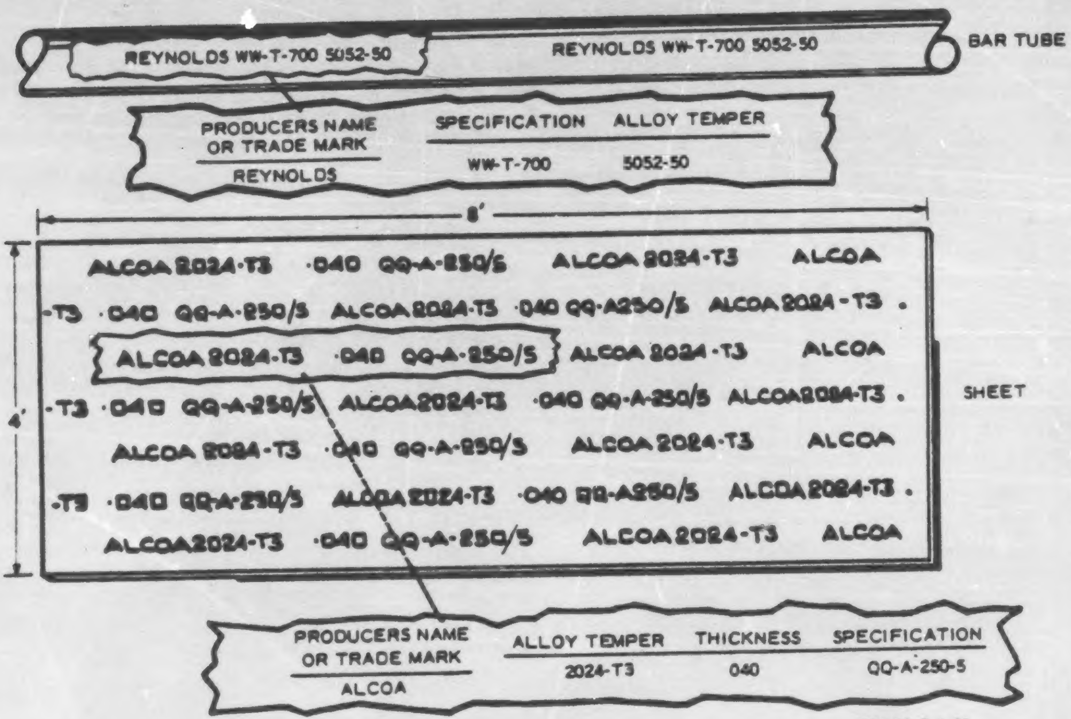
1-74. *Specifications.* Earlier we discussed the four-digit index system for classification of aluminum alloys by their material content. We now go to the specification system (the system that tells the manufacturer how much of those materials to incorporate into the production of each of those alloys desired by the Government).

1-75. Metal, when marked, should show both the metal classification and the specification. See figure 3 for a sample format of how sheet, bar, and tube should be marked according to Federal specifications. To use these markings properly, you must have an understanding of the specifica-

---

* Used to denote normalized temper

** Used to denote aircraft quality


REYNOLDS WW-T-700 5052-50
REYNOLDS WW-T-700 5052-50
BAR TUBE
PRODUCERS NAME OR TRADE MARK
REYNOLDS
SPECIFICATION
WW-T-700
ALLOY TEMPER
5052-50
8'
4'
ALCOA 2024-T3 ·040 QQ-A-250/5 ALCOA 2024-T3 ALCOA
-T3 ·040 QQ-A-250/5 ALCOA 2024-T3 ·040 QQ-A250/5 ALCOA 2024-T3
ALCOA 2024-T3 ·040 QQ-A-250/5 ALCOA 2024-T3 ALCOA
-T3 ·040 QQ-A-250/5 ALCOA 2024-T3 ·040 QQ-A-250/5 ALCOA 2024-T3
ALCOA 2024-T3 ·040 QQ-A-250/5 ALCOA 2024-T3 ALCOA
-T3 ·040 QQ-A-250/5 ALCOA 2024-T3 ·040 QQ-A250/5 ALCOA 2024-T3
ALCOA 2024-T3 ·040 QQ-A-250/5 ALCOA 2024-T3 ALCOA
SHEET
PRODUCERS NAME OR TRADE MARK
ALCOA
ALLOY TEMPER
2024-T3
THICKNESS
040
SPECIFICATION
QQ-A-250-5

53450-2-1-51

Figure 3. Marking of aluminum alloys.

tions. Table 2 contains a list of specifications of some of the commonly used alloys in the aircraft maintenance field. These specifications refer only to the material content requirements, and the specification number refers to the document which establishes requirements. The specifications do not identify the temper or hardness of the metal. For an airframe repairman to use these specifications, he must know what is required in the material composition and hardness specified by the appropriate –3 technical order, microfilm, or other technical data which signifies repair material.

1-76. **Heat-Treatment.** To increase the strength of aluminum, it is alloyed with various other metals to form the so-called "strong alloys" for aircraft structural usage. Heat-treatment further improves the desired strength and hardness of those alloys by heating, quenching, and aging. The principal alloying constituent shows a worked increase in solid solubility at elevated temperatures. The accepted explanation for the heat-treatment of aluminum alloys is that the high solid solubility of the alloying materials at elevated temperatures corrects certain segregation effects that occur during solidification of the liquid alloy, and the smaller solubility at lower temperatures effectively distributes the hardening agents throughout the metal.

1-77. The first operation in heat-treatment consists of holding the alloy at a temperature as high as practicable without the danger of melting any of the constituents. The metal is then cooled so rapidly that the dissolved constituents do not precipitate in accordance with the lower solubility at the lower temperature.

1-78. Alloy is heated in either an electric air furnace or a nitrate bath (see fig. 4) heated by oil, gas, or electricity. All furnaces must be

TABLE 2

MATERIAL—SPECIFICATION CROSS-REFERENCE

Commercial Sheet Alloy Designation	Federal Specification
1100	QQ-A-250/1
2024	QQ-A-250/4
Alclad 2024	QQ-A-250/5
3003	QQ-A-250/2
5052	QQ-A-250/8
6061	QQ-A-250/11
7075	QQ-A-250/12
Alclad 7075	QQ-A-250/13
7178	QQ-A-250/14
Alclad 7178	QQ-A-250/15

53450-2-2-T2

equipped with accurate temperature measuring and controlling devices to insure maintenance of uniform temperature. The potentiometer type of instrument is preferred. Circulation of the heating medium (either air or nitrate bath) increases the heating rate and is very desirable.

1-79. A temperature survey is made of the furnace or bath at frequent intervals to determine if there are hot spots that might cause local overheating of the aluminum alloy being heat-treated. The charge will be small enough so that a large temperature drop does not occur in the furnace or salt bath when the charge is inserted.

1-80. When several parts are treated together, they are placed so the heating element circulates freely about them. Separate parts whose soaking time differs by more than four to one are not heat-treated in the same charge.

1-81. The salt bath in figure 4 used for heat-treating aluminum alloy consists of a mixture of equal weights of potassium nitrate and sodium nitrate. The melting point of this bath is approximately 450° Fahrenheit and the recommended working range is 550° Fahrenheit. At the normal heat-treating temperature of approximately 1000° Fahrenheit, aluminum alloys can be treated in nitrate baths without danger. However, at 1100° Fahrenheit and above, the salt decomposes, causing foaming of the bath, and a reaction takes place between the nitrate, the aluminum castings, and the iron oxide of the tank. These reactions liberate considerable heat and may cause fires and explosions. Therefore, extreme care is taken to regulate the temperature of nitrate salt baths to prevent overheating.

1-82. Additions of a similar mixture are made to the bath, and no other salt or chemical is added. Since the addition of common salt (sodium chloride), sodium or potassium nitrate, or other salts raise the melting point of the bath very rapidly, they are not added.

1-83. You can control the circulation of the salt bath by alternately raising and lowering the metal charges, but you must be sure that no portion of the metal is raised above the surface of the bath.

1-84. The salt bath is not used for heat-treating parts of assemblies that cannot be thoroughly washed to remove the salt solution.

CAUTION: Cyanide salts and other material containing carbon or sulphur are not added to

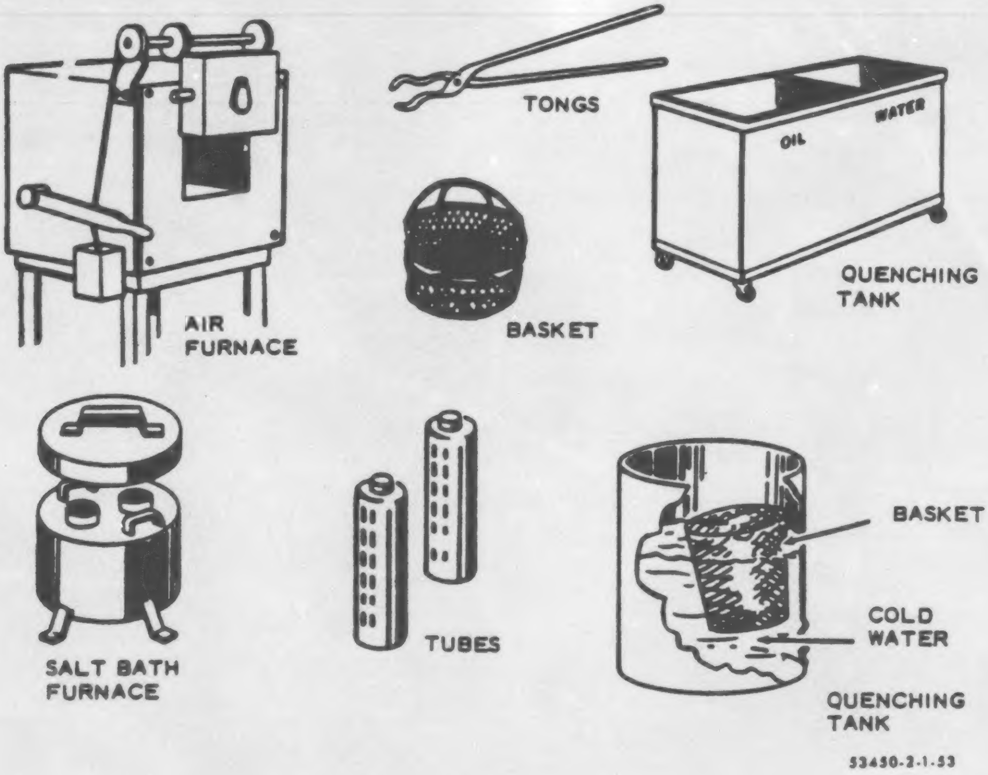


Figure 4. Heating and quenching equipment.

67

TABLE 3
HEAT-TREATING PROCEDURES

Commercial Designation No.	Annealing Temp., °F for relief of hardness caused by: Cold Work	Heat Treatment	Solution Treatment Temp. °F.	Time Hrs.	Quench	Aging Treatment Temp. °F.	Time Hrs.	Tensile Strength Lb. Sq. Inch
2015	750-800	650-800	925-950	.5-6 (2)	Cold water	340-360	5-14	65,000
2017	640-670	750-800	925-950		Cold water	Room		55,000
Alclad 2017	640-670		925-950		Cold water	Room		50,000
2024	640-670	750-800	910-930		Cold water	Room		62,000
Alclad 2024	640-670		910-930		Cold water	Room		56,000
2024	240-670	750-800	910-930		Cold water	370-380	M/Less than 6 hrs.	60,000 72,000
Alclad 7075	440-460	775-850	860-930		Cold water	240-260	24	70,000
7178	440-460	775-850	860-930		Cold water	240-260	24	83,000
Alclad 7178	440-460	775-850	860-930		Cold water	240-260	24	78,000
6061	640-670	750-800	960-980		Cold water	315-325	12-18	42,000
142			950-980	2-16	Hot water (1)	400-450	1-3	32,000
195			940-970	2-24	Hot water (1)	300-320	1-6	32,000
355			960-990	4-12	Hot water (1)	300-320	1-6	32,000
356			980-1010	4-12	Hot water (1)	300-320	1-6	30,000
1100	625-700		980					15,500
3003	725-700							19,000
3004	725-775							29,000
5052	625-700							31,000
2018			940-970	.5-6 (2)	Boiling water	330-350	4-12	55,000
4032			940-970	.5-6 (2)	Boiling water	330-350	4-12	50,000

(1) Water at 150-212 °F.
(2) This figure is for thickness up to 2 inches.
Material over 3 inches should be soaked 2 to 12 hours.

53450-2-2-T3

salt baths, since even small quantities (such as adhere to cyanide steel) may cause serious explosions. Magnesium or magnesium alloys are never placed in hot salt bath as an explosion may occur.

1-85. In operating salt baths, take the following safety precautions to prevent fire and explosions:

- Check pyrometers and thermocouples daily.
- Clean and examine tanks and clean soot from the burners and tubes at the end of each 30 days of operation or oftener if needed.
- Remove any cyanides or other organic matter from the vicinity of the tank.
- Adjust burners so that the heat input is slightly greater than the heat loss in the tank.

1-86. Aluminum alloys are annealed by heating and soaking at the temperatures specified in tables 3 and 4 for the particular alloy, and then cooling in air or in a furnace. The length of time of heating depends upon the thickness of the material and the amount of cold-working to be performed. Tubes for cold-swaging require a very soft anneal. For example, specification WW-T-785 is held at a temperature of 700° to 800° Fahrenheit for 3 hours and then furnace cooled to about 400° Fahrenheit. The remainder of the cooling is in air.

1-87. The time for annealing is made as short as possible because a long anneal causes grain growth and loss in ductility. In the case of clad materials, the copper constituent tends to diffuse through the pure aluminum coating, reducing the effectiveness of the pure aluminum as a corrosion-resistant covering.

1-88. When necessary, clad materials are annealed by heating and cooling in air or in a furnace. They are not annealed at high temperatures. Parts manufactured from the heat-treatable alloys, such as specifications WW-T-785, QQ-A-250/5, and QQ-A-250/13, are not used in the annealed condition.

1-89. Bars, sheets, tubes, and castings are heated in the salt bath or furnace for the length of time and temperature indicated in table 3. The time stated is actual time at temperature for all parts of the charge in a noncirculation medium. If the charge is large, it is desirable to place a thermocouple in the center of the charge and time the soaking period from the time the thermocouple comes up to temperature. The optimum soaking time depends on the type of heating medium (a salt bath heats most rapidly; forced air heats more rapidly than still air), type

74

of alloy, the previous thermal and mechanical treatment, and size and shape of the part.

1-90. Aluminum alloys 2017 and 2024 (nonclad) are always quenched in cold water. Alloy 2014 is quenched in cold or hot water, depending on the thickness of the section. Quenching keeps the alloying constituents of the material in solid solution as they are at the indicated heated temperature.

1-91. Aluminum alloys cool rapidly when removed from the furnace atmosphere or salt bath. To assure corrosion resistance and effective heat-treatment, quenching tanks *must* be located close to the furnace and the transfer from furnace to tank *must* be handled with maximum speed. All parts of the charge *must* be completely immersed.

1-92. The two operations of heating and quenching are called the solution treatment. This treatment causes some increase in strength and hardness over that of the annealed condition. The maximum strength and hardness are not immediately obtained, and the ductility is not appreciably affected. Prior hardening due to mechanical working is removed by this treatment.

1-93. After the solution heat-treatment, age-hardening alloys tend to harden gradually. After certain period of time at the specified aging temperature, dependent upon the composition and thickness of the material, the alloy attains maximum strength and hardness. Some alloys attain full strength by aging at room temperature for approximately 4 days (2024 and 2017), while others must be aged at elevated temperatures to obtain full strength (2014 and 7075).

1-94. Alclad 2014 aluminum alloy sheet and extruded shapes must be artificially aged at 310° to 330° Fahrenheit for 18 hours or at 345° to 355° Fahrenheit for 6 hours to attain full strength subsequent to solution heat-treatment.

1-95. Aluminum alloy 2017 is not usually given an elevated temperature aging treatment, but is aged for a period of 4 days at room temperature subsequent to solution heat-treatment to attain full strength in the T4 condition.

1-96. Aluminum alloy 2024 bar, rod, shapes, and sheet should be aged at room temperature for a period of at least 4 days subsequent to the solution heat-treatment for attainment of full strength. However, it has been found that the physical properties of this alloy may be increased by elevated temperature precipitation (aging) treatment.

TABLE 4

SOAKING PERIODS FOR HEAT-TREATMENT OF ALLOYS 2014, 2017, ALCLAD 2017, 2024, 6053, AND 6061

Thickness of Sheet	Air Furnace		Salt Bath	
	Minimum Soaking Time	Maximum Soaking Time for Alclad 2017, Alclad 2024	Minimum Soaking Time*	Maximum Soaking Time for Alclad 2017, Alclad 2024
Inches	Minutes	Minutes	Minutes	Minutes
Up to .020	5	15	5	15
.021 to .032	10	20	10	20
.033 to .063	20	30	14	25
.064 to .125	30	40	20	30
.126 to .250	50	70	20	30
.251 to .500	90	110	30	40

*Minimum soaking periods will be sufficient for the heat treatment of rivets in practically all cases.

53450—2—2—T4

69

1-97. **Parts fabricated from Alclad 2024 aluminum sheet and given an elevated temperature precipitation treatment may be in one of three forms.** The code symbols for the forms are 2024–T6, 2024–T81, or 2024–T86. The T in the code symbol followed by a number designates one specific combination of basic operations (example: 2024–T3). If some variation of the same basic operation should be applied to the same alloy, resulting in different characteristics, then other digits are added to the basic designation. For example, clad 2024–T3 stretched (cold-worked) approximately 6 percent becomes 2024–T36. In this case, the number 6 indicates a different amount of stretching than that used in 2024–T3, which is stretched only enough for flattening (approximately 1 percent).

1-98. The aging treatment for the clad 2024 alloy consists of heating at 375° Fahrenheit plus or minus 5° for not less than 5 hours. The solution heat-treatment temperatures and soaking time are given in tables 3 and 4.

1-99. Bare and clad 7075 and 7178 aluminum alloys are artificially aged at 250° to 260° ~~260° to 280°~~ Fahrenheit for 24 hours for attainment of full strength. Artificial aging is accomplished in an electric furnace or enameling oven which is uniform in temperature and capable of controlling temperature within plus or minus 5° Fahrenheit. Care must be exercised in charging to avoid hot spots or restricted circulation.

1-100. The following may be used as an alternate aging treatment for 7075 aluminum alloy in thicknesses less than 0.5 inch: Heat at 230° to 250° Fahrenheit for 3 to 4 hours, then heat at 315° to 335° Fahrenheit for 3 to 4 hours. Temperatures may be raised directly from lower to higher, or the load may be allowed to cool between the two steps of the treatment.

1-101. When a salt bath is used for heat-treatment of aluminum alloys, all traces of salt must be removed by washing in hot water, following the quench in cold water. The cleaning should be done rapidly so that the parts will be in hot water the shortest time practicable. A dark stain sometimes remains which does not usually affect the strength of the material.

1-102. Aluminum alloys strain-harden when they are worked. This strain-hardening, plus the initial heat-treating process, may cause the metal to become harder than desired. Occasionally, when working with aluminum alloys stock, it may become necessary for you to remove the hardness to avoid danger of breaking or cracking the metal. To do this, it must be annealed or softened. Annealing removes the strain-hardening which results from cold-working, and in the case of the heat-treated alloys, removes the effects of the heat-treatment. Annealing is usually carried out in air furnaces, but salt baths may be used if the melting point of the bath is low enough.

1-103. For the complete removal of the effects of heat-treatment, the alloy must be heated to a temperature of 750° to 800° Fahrenheit. The alloy is held at 750° to 800° Fahrenheit long enough to permit all parts of the alloy to remain at that temperature for at least 1 hour. The alloy is then allowed to cool at a maximum of 50° Fahrenheit per hour until the temperature has reached 500° Fahrenheit. The rate of cooling below 500° Fahrenheit is not important. Occasionally, for minor forming operations, only a partial anneal may be sufficient. For partial annealing, an initial heating to approximately 650° Fahrenheit may be sufficient and the rate of cooling is not important.

1-104. To anneal material that was initially in the soft or annealed condition (1100, 3003, 6053, etc.) but was strain-hardened by cold-working, use the following process: Heat the material to a temperature of 660° ± 10° Fahrenheit, hold it to this temperature only long enough to make certain that all parts of the stock reach that temperature, then let it cool at room temperature.

1-105. When annealing ~~treating~~ pure aluminum covered alloys (Alclad or Pureclad), heat them as quickly and carefully as possible, because long exposure to heat may cause some of the core constituents to diffuse into the pure aluminum coating and appreciably reduce its corrosion resistance. Never heat Alclad 2024 alloy to a temperature exceeding 810° Fahrenheit, and be sure the length of time the alloy is held at that temperature does not exceed 2 hours.

1-106. We have discussed the properties, index system, temper designations and other factors needed to determine the types of aluminum alloys. Now we will look at the procedures for getting the proper material. For example, if the particular –3 technical order specifies that the material needed to do a job is aluminum alloy, 2024–T3 0.040 inches thick and 2024–T3 0.050 inches thick, how do you obtain this material?

1-107. **Requisitioning.** The supply system and catalogs were identified and discussed in the previous volume of this course. We know that all we have to work with is aluminum alloy sheet, 2024–T3 0.040 and 0.050. You must first use the Cataloging Handbook H2–3, *Alphabetic Index*, to determine which group and class aluminum alloy comes under. Table 5 illustrates a sample of the extracted page which will apply to

TABLE 5
ALPHABETIC INDEX, H2-3 CATALOGING HANDBOOK (TYPICAL)

	CLASS
Aluminum acetate solution tablets, effervescent	**6505**
Aluminum alloy angles	**9540**
Aluminum alloy bars	**9530**
Aluminum alloy channels	**9540**
Aluminum alloy chips	**9535**
Aluminum alloy H-sections	**9540**
Aluminum alloy I-sections	**9540**
Aluminum alloy ingots	**9550**
Aluminum alloy plates	**9535**
Aluminum alloy rods	**9530**
Aluminum alloy sheets	**9535**
Aluminum alloy sheets, perforated	**9535**
Aluminum alloy special shaped sections	**9540**

53450—2—2—T5

the material we are looking for. Use table 5 and find aluminum Alloy Sheets. You will find that the class is 9535. This is your first lead in finding the necessary Federal Stock Number (FSN) for the needed aluminum.

1-108. The next step is to go to the Federal Supply Catalog. This is divided into two parts within the 9500 group of stock numbers, the C9500–IL–AF and C9500–ML–AF. The –IL– means the Identification List and –ML– means the Management Data List. First we must use the –IL– to identify the material with what information we now have.

1-109. The index of the C9500–IL–AF contains the alphabetical listing of the metals contained within the 9500 group and is cross-referenced to the table (where the item can be identified by composition, thickness, width, length, temper, tensile strength, and weight). In this particular case, let us use this index. Under –S– we find sheet, aluminum alloy, and the table referenced is table 291. In the –IL–, tables are set up numerically, so turn to table 291. Table 291 contains the identification of aluminum alloy, 2024, Alclad, Federal Specification QQ–A–250/5, aluminum-copper-magnesium-manganese, alloy, heat-treatable, applications where high strength with good resistance to corrosion is required. Our table 6 is a sample of how table 291 looks. Using the table we find that the index number and Federal Stock Number are listed first. Look through the material available on this table and you will see that index numbers 500 and 530 have the specifications that are needed to fulfill the requirements of the –3 technical order. They are 0.040 and 0.050, 2024–T3. Be-

TABLE 6

TABLE 291, C9500-IL-AF (TYPICAL)

Action Code	Index No	FSN FSC 9535	Thickness Inches	Width Inches	Length Inches	Temper	Min Tensile Strength PSI	Pounds per Sheet
	470	554-1416	.040	36	48	0	30,000	6.91
	480	167-2267	.040	36	144	0	30,000	20.73
	485	167-2280	.040	36	144	T-3	59,000	20.73
	490	167-2190	.040	36	144	T-86	66,000	20.73
	495	232-0494	.040	48	144	0	30,000	27.65
	500	232-0583	.040	48	144	T-3	59,000	27.65
	505	232-0453	.040	48	144	T-36	62,000	27.65
	525	232-0501	.050	48	144	0	30,000	34.56
	530	232-0569	.050	48	144	T-3	59,000	34.56
	535	232-0454	.050	48	144	T-36	62,000	34.56
	537	163-2191	.050	48	144	T-86	66,000	34.56
	540	288-0680	.050	48	288	T-3	59,000	69.12
	550	640-2311	.050	36	144	T-3	59,000	25.92
	565	232-0570	.050	60	144	T-3	59,000	43.20

53450-2-2-16

TABLE 7

TYPICAL PAGE OF C9500-ML-AF

Stock Number	Index No	Vol No	I/S	Issue and Fund Control	Status AF	Status DOD	Exp	Unit of Issue	Standard Price	Source of Category
9535-232-0535				SF		1	XB3	SH	80.00	KZ
9535-232-0543				SF	*	1	XB3	SH	13.80	KZ
9535-232-0550				SF		1	XB3	SH	15.40	KZ
9535-232-0565			I	SF			XB3	SH	16.00	KZ
9535-232-0569				SF	*	1	XB3	SH	18.70	KZ
9535-232-0583				SF		1	XB3	SH	16.60	KZ

53450-2-2-17

fore deciding on which particular sheets of aluminum to order, consider the size of the sheets. Notice that the sheets come in widths from 36 to 60 inches and the length varies from 48 to 288 inches. Most shops are equipped to handle and store the standard 48- by 244-inch sheets, so we decide to order those as they will also be sufficient for the job ahead. Now that we know what we want by Federal Stock Number, we must use the other part of the supply catalog to obtain the necessary information to actually requisition the material needed.

1-110. The C9500-ML-AF. Management Data List, is arranged numerically according to Federal Stock Number. The numbers we are looking for are in sequence by those stock numbers. Table 7 illustrates an extracted sample of how that portion of the -ML- is arranged. Our desired sheets of aluminum alloy are listed 9535-232-0583 and 9535-232-0569; we need one sheet of each of the materials. The primary parts of the -ML- that we need are the Federal Stock Number (FSN), expendability code (EXP), unit of issue, price, and source of category. Source of category tells us where supply will have to get the material.

NOTE: Prior to ordering material, always check the latest Change Bulletins of the -ML- and -IL- to be certain that the material desired is currently listed as stated in the Basic Federal Supply Catalog.

1-111. With the information obtained, the next step is to requisition the material on DD Form 1348, DOD Single Line Item Requisition System Document (Manual). Figure 5 shows the completed form and the entries needed to obtain the material. The DD Form 1348 is completed as follows:

- Block A: Initiating Shop.
- Block B: T.O. number, page, figure, and index number. (Not required when Federal Stock Number is entered in blocks 4 and 5.)
- Block C: Print last name of person initiating request.
- Block 4 and 5: Federal Stock Number, if available.
- Block 7: Unit of issue. Example: ea, gal, sh, etc.
- Block 8: Quantity Required.
- Block L: Noun and part number of item required.
- Block 22: BR. (Urgency justification code for AWP).
- Block P: Type of aircraft, end item, and part number.
- Block 23: Document number of reparable item from AFTO 200 series form authorizing work.

1-112. **Storage.** Technical Order 00-85A-23-1, *Preservation, Packaging and Storage*, states that the clad surface on aluminum provides adequate protection against corrosion if the material is kept dry; therefore, a contact preservative (oiling) is not required. It is essential, however, that clad surfaces be protected against scraches or abrasion, since damage will permit corrosion of the alloyed metals under the clad coating. To protect against this type damage, clad surfaces must be interleaved with minimum 15-pound basis weight paper between each two sheets of metal.

1-113. Bare (nonclad) surfaces of aluminum alloy are less resistant to corrosion, and, therefore, require coating of all surfaces including the edges (to impair corrosion attack) with a thin, even coat of oil.

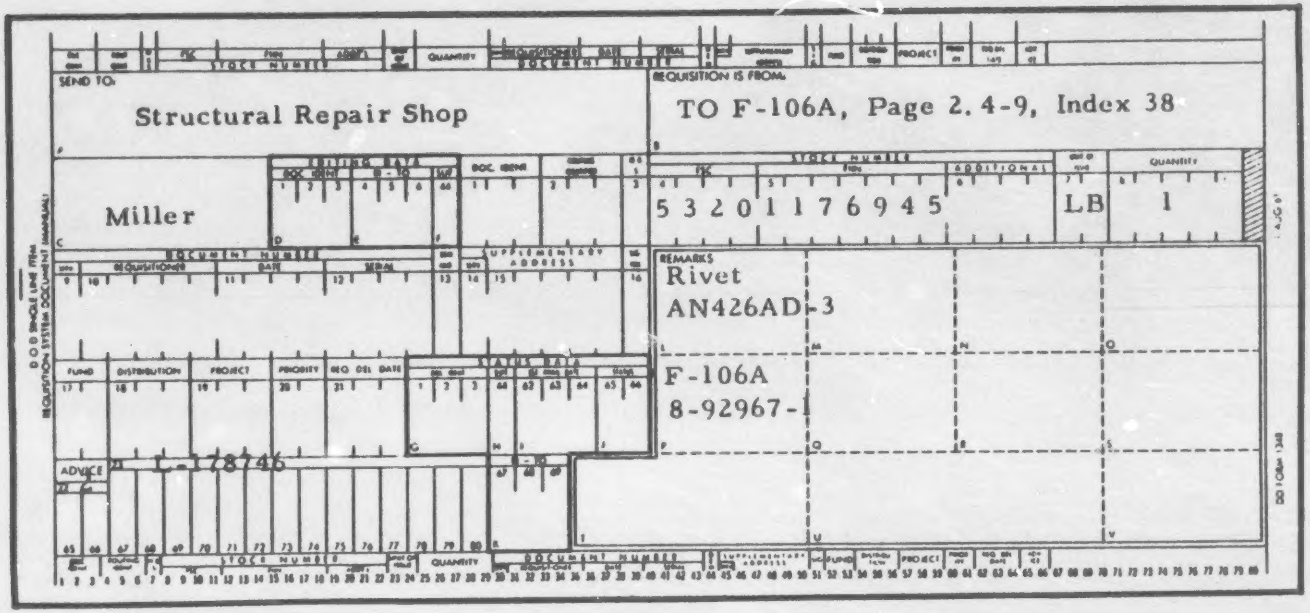
1-114. All aluminum alloy sheets are stored in dry, fully enclosed spaces, and are not exposed to weather and other corrosion-inducing conditions which render the material unusable. If aluminum is wet when delivered, dry it throughly before storage. This can be done in still air or by dry air currents. Once safely dried, the metal should not be stored near such obvious sources of moisture as steam or water pipes, and should be at such a distance from open doors and windows as to reduce the possibility of moisture. Be sure to keep stored aluminum away from such chemicals as caustics, nitrates, phosphates, and acids.

1-115. In the continuous use of large quantities of metal, the oldest stock should be used first. Occasional checking and rotation of stock eliminates any serious corrosion problems which may develop.

1-116. **Working Characteristics.** Working characteristics of aluminum are such that several precautions are taken to insure a safe and usable product after fabrication processes are completed.

1-117. *Drilling and punching.* Rivet or bolt holes in primary load-carrying members are drilled, or subpunched and reamed. The amount by which the diameter of a subpunched or pilot drilled hole is smaller than that of the finished hole should be at least one-quarter of the thickness of the piece, and in no case less than 1/32 of an inch. Both the single and multiple type punches, such as used on structural steel, are suitable for aluminum alloys. Cutting edges of both punches and dies should be kept sharp.

1-118. Reamers should be of the high-speed, spiral-fluted type. Reaming operations on alumi-



D O D SINGLE LINE ITEM REQUISITION SYSTEM DOCUMENT (MANUAL)

SEND TO: Structural Repair Shop

REQUISITION IS FROM: TO F-106A, Page 2. 4-9, Index 38

Miller

EDITING DATA

DOC. IDENT

STOCK NUMBER: 5 3 2 0 1 1 7 6 9 4 5

UNIT OF ISSUE: LB

QUANTITY: 1

DOCUMENT NUMBER

SUPPLEMENTARY ADDRESS

REMARKS:
Rivet
AN426AD-3
F-106A
8-92967-1

FUND

DISTRIBUTION

PROJECT

PRIORITY

REQ DEL DATE

STATUS DATA

ADVICE: L-178746

DD FORM 1348

Figure 5. DD Form 1348, DOD Single Line Item Requisition System Document (Manual).

74

num alloys are about twice as fast as the same work in steel.

1-119. Twist drills used on aluminum alloys work best when kept sharp and lubricated with a soluble oil when necessary. Drill speeds can be increased about 50 percent above those used for steel. Special drills with more than the normal number of twists per inch can be used to advantage where a large amount of work is to be done. A double-fluted twist drill with spiral angle of 47° gives good results on aluminum alloys.

1-120. *Cutting and shearing*. Sheet, plate, and shapes of alloys other than 7075–T6 in thicknesses of ½ inch or less can be sheared on any type of equipment used for other metals. Keep the blades sharp and the clearances adjusted to give smooth cuts. Material thicker than ½ inch is sawed or routed. In the case of 7075–T6, the limiting thickness is about 0.1 inch rather than ½ inch.

1-121. Straight and curved cuts can be made by saws. Lubricants of the soluble oil type are recommended when a lubricant is necessary. For straight cuts, stationary or portable circular saws are used; band saws are used for curved cuts. In any type of work, high blade speeds are desirable. A speed of 5000 feet per minute (fpm) is recommended for band saws. The saw teeth should be fairly coarse with a slight set and a slight amount of front rake.

1-122. *Forming*. Through proper choice of alloy, temper, forming methods, and tools, a great variety of forming operations can be performed on aluminum and aluminum alloys. Ordinary types of presses, brakes, and rolls are suitable for this work; but it is highly desirable that the surfaces of the tools that come in contact with the aluminum alloys be smooth and free from tool marks, dents, or rough edges which could tear or score the metal. For difficult operations, heavy oils or tallow mixed with a small amount of mineral oil can be used to advantage.

1-123. When you make bends that approach the minimum radius, keep the surfaces and edges of the metal smooth. Scratches, nicks, and sharp corners must be removed. Use a pencil rather than a punch or scriber to mark a bend line. Remember that the temper of material and thickness of metal for a given alloy determine the severity of forming that can be accomplished successfully.

1-124. If a given operation is too severe for the final temper of a heat-treated alloy, forming can be done either hot or cold on annealed material and strength developed by subsequent heat-treatment. Heat-treated alloys can also be formed at room temperature in the "fresh quenched" or "W" temper (which is more formable than the fully heat-treated temper). After forming is completed, the part is aged to develop full strength. Since alloys in the freshly quenched temper age-harden naturally at room temperature, maximum formability is available immediately after quenching.

1-125. **Inspection of Aluminum Repairs.** When you inspect completed repairs involving aluminum alloys, several questions must be answered satisfactorily before you approve the finished product.

- Is the material used in all reinforcement or replacement parts similar in composition and strength to the material in the original structure?
- When in acid or fume areas, has the material been properly protected by the recommended corrosion-preventive finish?
- If the metal has been formed, is the metal cracked at the bend lines?
- Has the material had proper heat-treatment?
- Is the surface of clad aluminum alloy free of scoring and scratches that defeat the cladding purpose?
- Has the applicable –3 technical order been followed for proper repair procedures to eliminate an unsafe repair and to preclude the necessity for repairing the area again?

1-126. Before continuing to Section 2, turn to the workbook and answer exercises for Section 1.

2. Titanium

2-1. Titanium was discovered shortly after the Revolutionary War by an English priest named Gregor. A crude separation of titanium ore was achieved in 1815. In 1906, a sufficient amount of pure titanium was isolated in metallic form to permit a study. In 1932, an extraction process was developed, which became the first commercial method for producing titanium. The United States Bureau of Mines began making titanium sponge in 1946, and 4 years later the melting process began.

2-2. The Kroll Process (named after Dr. Wilhelm Kroll), for the extraction of titanium from the ore, is used throughout the country. It is a batch operation requiring stringent control in order to maintain purity. The product of this process, titanium sponge, is a highly porous material subject to atmospheric contamination, unless suitably protected. Sponge is subsequently purified and compacted into electrodes for melting and remelting in the production of the final ingot (for casting). Titanium metal production, from ore to final ingot, usually follows the basic steps outlined, and is shown schematically in figure 6.

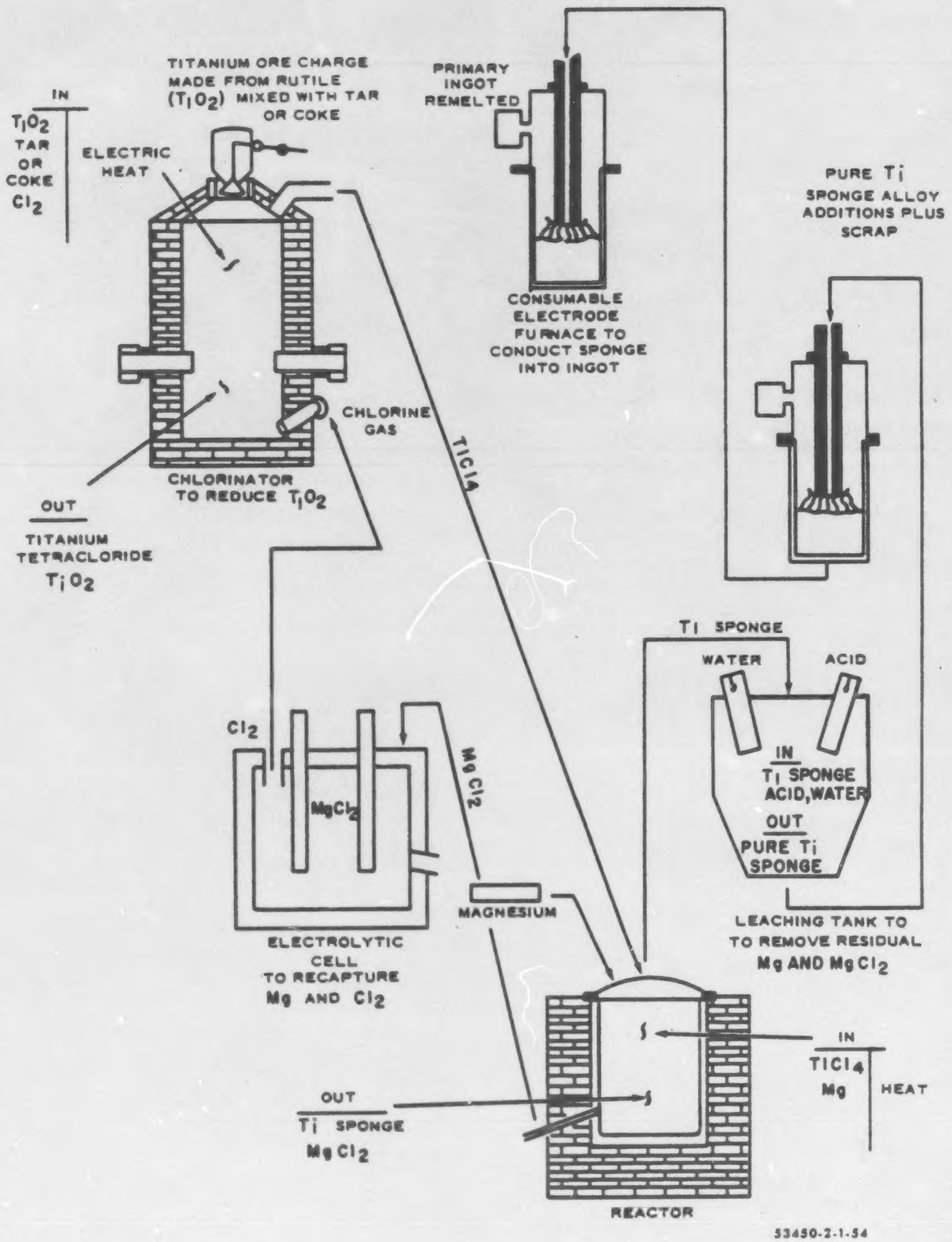

TITANIUM ORE CHARGE MADE FROM RUTILE (TiO_2) MIXED WITH TAR OR COKE
IN
TiO_2
TAR OR COKE
Cl_2
ELECTRIC HEAT
CHLORINE GAS
CHLORINATOR TO REDUCE TiO_2
OUT
TITANIUM TETRACLORIDE
TiO_2
PRIMARY INGOT REMELTED
CONSUMABLE ELECTRODE FURNACE TO CONDUCT SPONGE INTO INGOT
PURE Ti SPONGE ALLOY ADDITIONS PLUS SCRAP
$TiCl_4$
Ti SPONGE
WATER
ACID
IN
Ti SPONGE ACID, WATER
OUT
PURE Ti SPONGE
LEACHING TANK TO TO REMOVE RESIDUAL Mg AND $MgCl_2$
Cl_2
$MgCl_2$
$MgCl_2$
MAGNESIUM
ELECTROLYTIC CELL TO RECAPTURE Mg AND Cl_2
IN
$TiCl_4$
Mg
HEAT
OUT
Ti SPONGE
$MgCl_2$
REACTOR
53450-2-1-54

Figure 6. How titanium is made.

a. Chlorination-Rutile ore (TiO_2) is reacted with chlorine gas at elevated temperatures to yield titanium tetrachloride ($TiCl_4$), a colorless liquid.

b. Magnesium Reduction—The $TiCl_4$ is combined with molten magnesium metal in a steel reactor under a controlled atmosphere to yield titanium metal in sponge form. Magnesium chloride ($MgCl_2$) is a byproduct. (The $MgCl_2$ is electrolyzed to recapture chlorine gas and magnesium metal, both of which are recycled through the process.)

c. Leaching—Titanium sponge is placed in leaching tanks where acid and water remove trace quantities of magnesium chloride and residual magnesium.

d. Melting—Titanium sponge is pressed into electrodes (with whatever alloying elements there are to be added). An electric arc melts the electrode into a primary ingot, which is remelted into a final ingot in a consumable arc vacuum furnace.

2-3. The use of titanium is widespread. It is used in many commercial enterprises and is in constant demand for such items as pumps, screens, and other tools and fixtures where corrosion attack is prevalent. In aircraft construction and repair, titanium is used for fuselage skins, engine shrouds, firewalls, longerons, frames, fittings, air ducts, fasteners, and many other parts. Titanium plays an important role in many of the seaplanes being manufactured. The Martin Sea Master contains over 500 components of titanium and titanium alloys. This aircraft contains one bulkhead 30 by 45 inches constructed entirely of commercially pure titanium sheet.

2-4. **Crystal Structure.** In the solid state each metal has a prevalent and characteristic formation of its atoms. The arrangement of this structure has definite influence on the characteristics of the metal. Alloying can alter structures or produce a combination of structures.

2-5. The A-B-C classification of titanium alloys was established to provide a convenient and simple means of describing all titanium alloys. Titanium alloys possess three basic types of crystals: A-(alpha), B-(beta), and C-(combined alpha and beta). Their characteristics are as follows:

2-6. *Alpha alloy*. The single-phase microstructure of the alpha alloys of titanium promotes good weldability. The stabilizing effect of the high aluminum content of this group of alloys assures excellent strength characteristics and oxidation resistance at elevated temperatures in the range of 600° to 1100° Fahrenheit. Alpha alloys cannot be heat-treated, since they are single-phase alloys.

2-7. Most of the alpha alloys contain some beta-stabilizing alloying elements. The composition of these alloys is balanced by high aluminum content, so the alloys are essentially one-phase alpha. The alpha alloys have two main attributes: Weldability (resulting from the one-phase microstructure), and retention of strength at high temperatures (resulting from the presence of aluminum). Alloying elements in solution strengthen the alpha-phase alloys. Aluminum is the most effective strengthener of alpha alloys; especially important is that its effect presists to elevated temperatures. Strengthening effects of carbon oxygen, and nitrogen disappear somewhere above 500° to 800° Fahrenheit. (These elements also have embrittling effects above low concentration limits.) Hot-working of alpha alloys containing more than about 6 percent aluminum is difficult. Hot workability of high-aluminum alpha is improved by additions of beta-stabilizing alloying elements in amounts small enough so that the beta phase is present in small quantities in the mill annealed microstructure.

2-8. *Beta alloy*. Beta alloys have good bendability, excellent ductility, are strong both hot and cold, but vulnerable to contamination. They are big consumers of strategic alloys. The high percentage of beta-stabilizing elements chromium, columbian, copper, iron, manganese, molybdenum, tantalum, and vanadium incorporated in the alloying of titanium make the alloy weldable; and more important, alpha-beta alloys can be strengthened by heat-treatment because their microstructure can be manipulated by controlled heating, quenching, and aging cycles.

2-9. One commerically available titanium alloy, Ti–13V–11CR–3A1, is considered a beta alloy (see table 8); strictly speaking, however, it is a metastable alloy. Its microstructure is predominantly beta phase after normal titanium annealing procedures. The alloy is weldable in both the annealed (single phase) and heat-treated conditions. Unlike the alpha alloys, this beta alloy can be strengthened by heat-treatment. Aging at elevated temperature after solution treatment results in precipitation of fine particles of alpha and titanium-dichromium ($TiCr_2$) compound. Ultimate strength up to 215 kilograms per square inch and 5 percent elongation are possible after heat-treatment. This is an increase over the annealed strength of at least 50 percent. Aging response of this alloy varies according to hot- or cold-working history and annealing procedures.

2-10. *Alpha-beta alloy*. Combined alpha and beta alloy is used for compromise performances. It is strong when cold or warm, but weak when

TABLE 8

TITANIUM DESIGNATIONS—COMMERCIAL AND SEMICOMMERCIAL TITANIUM MILL PRODUCTS

Nominal Composition, weight per cent	Crucible	Producer's Designations		TMCA	AMS	Other Designations		Mill Forms(1)
		Mallory-Sharon	Republic			ASTM	Military	
TYPE I - Unalloyed Titanium								
High purity (99.9%)[2]	--	--	--	--		—		
Commerical purity (99.2%)	A-40	MST-40	RS-40	Ti-35A(3)	4902	B-265-58T-Gr2	T-9047B-1	a, b, c, d, e, f, g, h
Commercial purity (99.0%)	A-55	MST-55	RS-55	Ti-65A	4900A	B-265-58T-Gr3	T-9047B-1	a, b, c, d, e, f, g, h
Commercial purity (99.0%)	A-70	MST-70	RS-70	Ti-75A Ti-100A	4901B 4921	B-265-58T-Gr4	T-9047B-1	a, b, c, d, e, f, g, h
TYPE II - Alpha Titanium Alloys								
Ti-5Al-2.5Sn	A-110AT	MST-5Al-2.5Sn	RS-110C	Ti-5Al-2.5Sn	4926	B-265-58T-Gr6	T-9047B-2 T-9046B-3	a, b, c, d, e, f, g, h
Ti-6Al-4Zr-1V	--	--	--	Ti-6Al-4Zr-1V	—	—	—	c, d
Ti-8Al-1Mo-1V	--	--	--	Ti-8Al-1Mo-1V	—	—	—	a, b, d
Ti-8Al-2Cb-1Ta	--	MST-821	--	--	—	—	—	a, b, c, d, g
Ti-8Al-8Zr-1(Cb+Ta)	--	MST-881	--	--	—	—	—	a, b
Ti-Zr-Al(4)	A-120ZA	--	--	--	—	—	—	a, b
TYPE III - Alpha Beta Titanium Alloys								
Ti-3Al-2.5V	--	MST-3Al-2.5V	--	--	—	—	—	e, f
Ti-5Cr-3Al	--	MST-3Al-5Cr	--	--	4927	—	T-9047B-3	a, b, e
Ti-2Fe-2Cr-2Mo	--	--	--	Ti-140A	4923	—	T-9046B-4 T-9047B-4	a, b, d, e, f
							T-9046B-1	c, d, e
Ti-8Mn	C-110M	MST-8Mn	RS-110A	--	4908A	B-265-58T-Gr7	T-9047B-6	a, b, c, g
Ti-4Al-4Mn	C-130AM	MST-4Al-4Mn	RS-130	--	4925A	—		c, d
Ti-4Al-3Mo-1V	C-115AMoV	--	RS-115	Ti-4Al-3Mo-1V	—	—	—	a
Ti-4Al-4Mo-4V	--	--	--	Ti-4Al-4Mo-4V	—	—	—	a, b, c, d
Ti-5Al-2.75Cr-1.25Fe	--	--	RS-140	--	—	—	—	
Ti-5Al-1.5Fe-1.4Cr-1.2Mo	--	--	--	Ti-155A	4929	—	T-9047B-7	a, b, c
Ti-6Al-4V	C-120AV	MST-6Al-4V	RS-120A	Ti-6Al-4V	4911 4928	B-265-58T-Gr5	T-9046B-2 T-9047B-5	a, b, c, d, e, f, g, h
Ti-7Al-4Mo	C-135AMo	--	RS-135	Ti-7Al-4Mo	—	—	—	a, b, g, h
Ti16V-2.5Al	C-105VA	MST-16V-2.5Al	--	--	—	—	—	a, b, c, d, e, g
TYPE IV - Beta Titanium Alloys								
Ti-13V-11Cr-3Al	B-120VCA	--	RS-120B	Ti-13V-11Cr-3Al	--	--	--	a, b, c, d, e, g

(1) a, bar; b, billet; c, plate; d, sheet; e, strip; f, tubing; g, wire; h, extrusions. Note: Specifications do not cover all mill forms.

(2) This classification includes iodide process crystal bar and products from newer processes such as electrolysis of fused-salt baths. Among producers recognized in the field from whom material may be available on a limited basis are National Distillers, Bureau of Mines, New Jersey Zinc, and Foote Mineral.

(3) Softer grades designated Ti-35A (35,000 psi yield strength) and Ti-45A (45,000 psi yield strength) also available.

(4) Composition not finalized; formerly RC 900 (Ti-12Zr-4.5Al).

53450-2-2-78

hot. It has good bendability, moderate contamination resistance, and excellent forgeability. The addition of controlled amounts of beta-stabilizing alloying elements causes the high-strength beta phase to persist below the beta transus temperature, thus resulting in a two-phase system. Such two-phase titanium alloys can be significantly strengthened by heat-treatment; i.e., by a quench from some temperature in the alpha-beta range, followed by an aging cycle at a somewhat lower temperature.

2-11. The transformation of the beta phase which occurs on slow cooling is suppressed by the quenching. The aging cycle causes the precipitation of some fine alpha particles from the metastable beta, imparting a structure that is stronger than the annealed alpha-beta structure.

2-12. **Characteristics.** Titanium and titanium alloys are used in engineering design chiefly for their relatively light weight and corrosion resistance coupled with good mechanical properties. Titanium has a high strength-to-weight ratio, high corrosion resistance, high oxidication resistance, low coefficient of thermal expansion, and low heat-treating temperature during hardening.

2-13. *Strength-to-weight ratio.* Although titanium is about 43 percent ligher than steel, it can often (on a strength-to-weight basis) be equated to steels having yield strength levels approximating 300 kilograms per square inch. Compared to aluminum, titanium alloys (60 percent heavier than aluminum) are much stronger, and show a higher fatigue resistance and greater hardness.

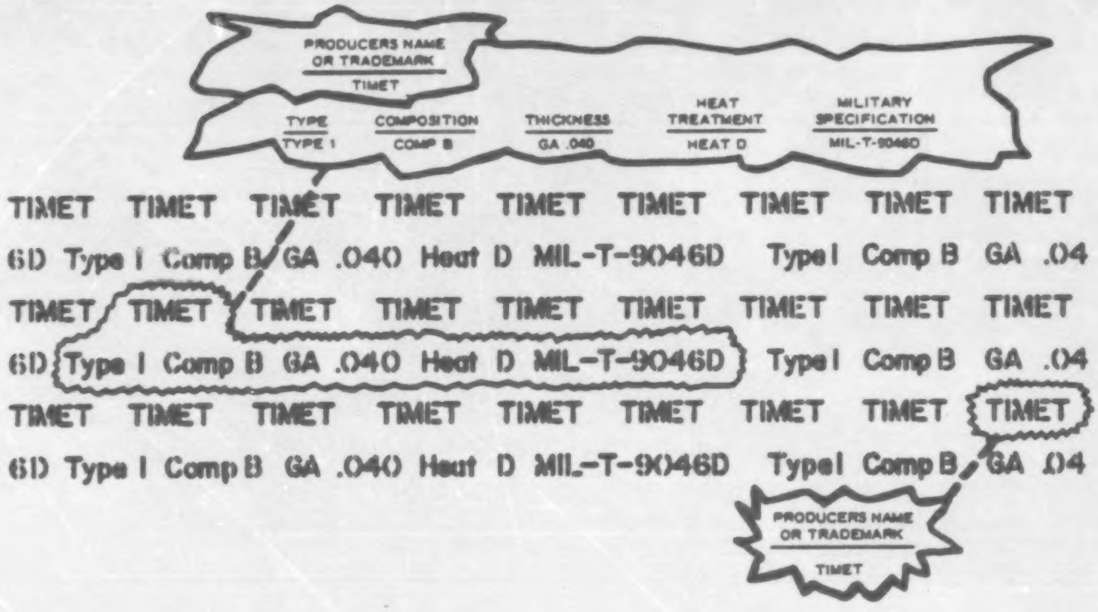
2-14. *Corrosion resistance.* The corrosion resistance of titanium is excellent, due mainly to the tenacity of its natural oxide surface. It is equal to, or better than, most metals in resistance to direct chemical corrosion by a wide variety of chemicals and is generally resistan~~ce~~t to stress corrosion, erosion-corrosion, galvanic corrosion, and oxidation. (The types and prevention of corrosion affecting titanium will be covered in detail in Chapter 2 of this volume.) Titanium is highly

TABLE 9

CONVERSIONS FOR TITANIUM ALLOYS

TYPE/COMP	MILITARY	AMS	TYPE/COMP	MILITARY	AMS
Unalloyed 40,000 psi yield	MIL-T-9046D Type I Comp A	4902		MIL-T-9047C	
Unalloyed 70,000 psi yield	Comp B	4901	Unalloyed 70,000 psi yield	Class 1	4921
Unalloyed 55,000 psi yield	Comp C	4900	5AL-2.5Sn	Class 2	4926
	TYPE II Alpha		3AL-5Cr	Class 3	4927
5AL-2.5Sn	Comp A	4910	2Fe-2Cr-2Mo	Class 4	4923
5AL-2.5Sn-EL1	Comp B		6AL-4V	Class 5	4928
5AL-5Zr-5Sn	Comp C		4AL-4Mn	Class 6	4925
7AL-12Zr	Comp D		5AL-1.5Fe1.5Cr1.5Mo	Class 7	4929
7AL-2Cb-1Ta	Comp E				
8AL-Mo-1V	Comp F				
	TYPE III Alpha-Beta				
8Mn	Comp A	4908			
1AL-3Mo-1V	Comp B	4912			
6AL-4V	Comp C	4911			
6AL-4V-EL1	Comp D				
6AL-6V-2Sn	Comp E				
7AL-4Mo	Comp F				
	TYPE IV Beta				
13V-11Cr-3Al		4917			

53450-2-2-T9


PRODUCERS NAME OR TRADEMARK
TIMET
TYPE
TYPE 1
COMPOSITION
COMP B
THICKNESS
GA .040
HEAT TREATMENT
HEAT D
MILITARY SPECIFICATION
MIL-T-9046D
TIMET TIMET TIMET TIMET TIMET TIMET TIMET TIMET TIMET
6D Type I Comp B GA .040 Heat D MIL-T-9046D Type I Comp B GA .04
TIMET TIMET TIMET TIMET TIMET TIMET TIMET TIMET TIMET
6D Type I Comp B GA .040 Heat D MIL-T-9046D Type I Comp B GA .04
TIMET TIMET TIMET TIMET TIMET TIMET TIMET TIMET TIMET
6D Type I Comp B GA .040 Heat D MIL-T-9046D Type I Comp B GA .04
PRODUCERS NAME OR TRADEMARK
TIMET

53450-2-1-55

Figure 7. Marking of titanium.

resistance to attack in various types of atmospheres and water even after long exposure. The corrosion resistance of the various titanium alloys has not been investigated as extensively as that of the commercially pure grades; however, available data indicates that the general corrosion resistance characteristics of titanium are not impaired by alloying.

2-15. When exposed to various types of atmospheres for extended periods of time, commercially pure titanium retains its luster.

2-16. Long term studies indicate that titanium in sea water and marine environments is resistant to pitting, stress corrosion, galvanic corrosion, and corrosion fatigue. The tensile properties of titanium alloys are generally unaffected by prolonged exposure to a marine environment.

2-17. Titanium is considered a noble metal in the same category as passive stainless steels. When coupled with aluminum and zinc, titanium, like stainless steels, does not form soluble corrosion products that can accelerate attack on these metals by plating-out action. Accelerated galvanic attack of the less noble metals, when coupled with titanium, is likely to result. Under corrosive conditions, the coupling of titanium to monel may result in slight corrosive attack on the latter.

2-18. The corrosion resistance of titanium is ascribed to a thin, stable, continuous film of oxide or absorbed oxygen which readily forms at low temperatures. As a result, the metal withstands reducing media and is more resistant to corrosion in the presence of oxidizing agents.

2-19. The resistance to corrosion, particularly galvanic corrosion, has certain limitations. With increasing temperatures, the thickness and permeability of the protective oxide film increases to the point where oxygen diffuses into the metal and produces embrittlement and corrosion. This tendency limits the use of titanium where high temperatures are encountered.

2-20. In general, titanium is almost unaffected by inorganic salts, organic reagents, and low concentration of inorganic acids. It is completely resistant to stress corrosion when subjected to the common test reagents.

2-21. *Thermal conductivity.* Titanium is a metal between aluminum and stainless steel in terms of modulus of elasticity, density, and elevated temperature strength. It has a melting point of 2730° to 3155° Fahrenheit, low thermal conductivity, and low coefficient of expansion.

2-22. **Identification.** Titanium is similar in appearance to stainless steel. One quick method used to identify titanium is the spark test. Titanium gives off a brilliant white trace ending in a brilliant white burst. Identification can be made by moistening the titanium and drawing a line on a piece of glass. This will leave a dark line similar in appearance to a pencil mark. Titanium is nonmagnetic.

2-23. *Designations.* To date, there is no single accepted system for the designation or classification of titanium and its alloys such as there is for steel; e.g., the American Iron and Steel Institute (AISI), or the Society for Automotive Engineers (SAE) systems. Several systems have been tried; none has won unanimous acceptance. They were based on one or more of three characteristics: chemical composition, alloy phase, and strength level. Today, much the same situation prevails.

2-24. Titanium and its alloys are referred to as commercial pure (an alpha form), or as an alpha, alpha-beta, or all-beta alloy. The basic alloying elements are given, such as Ti–6A1–4V (for titanium alloyed with 6 percent aluminum and 4 percent vanadium). Another commercial practice is to prefix the approximate yield strength of the alloy (in thousands of pounds per square inch) with the company initials, such as XYC–130. Digital systems are employed to designate certain alloys. The airframe repairman must be careful when specifying titanium alloys to insure that he gets the correct alloy composition, phase, and especially properties. Table 9 shows a chart prepared by the Defense Metals Information Center, showing the various titanium alloy compositions, producer's designations, military designations, and the forms in which manufactured. Other information on the designations and identifications of titanium can be found in Technical Order 1–1A–9, *Aerospace Metals—General Data and Usage Factors.*

2-25. *Metal marking.* Sheet titanium is

TABLE 10
RECOMMENDED MINIMUM COLD BEND RADII

TYPE/COMP	MINIMUM BEND RADIUS (90 DEGREE BEND) 1/	
	0.070 & under thickness	over 0.070 to 0.187
Type I - Commerically Pure		
Comp A (unalloyed 40,000 psi)	2T	2.5T
Comp B (unalloyed 70,000 psi)	2.5T	3T
Comp C (unalloyed 55,000 psi)	2T	2.5T
Type II - Alpha Titanium Alloy		
Comp A (5AL02.5Sn)	4T	4.5T
Comp B (5AL-2.5Sn EL1)	4T	4.5T
Comp C (5AL-5Zr-5Sn)	4.5T	5T
Comp D (7AL-12Zr)	5T	5T
Comp E (7AL-2Cb-1Ta)	--	--
Comp F (8AL-1Mo-1V)	4.5T	5T
Type III-Alpha-Beta		
Comp A (8Mn)	3T	3.5T
Comp B (4AL-3Mo-1V)	3.5T	4T
Comp C (6AL-4V)	4.5T	5T
Comp D (6AL-4V)	4.5T	5T
Comp E (6AL-6V-2Sn)	--	--
Comp F (7AL-4Mo)	--	--
Type IV - Beta		
Comp A (13V-11Cr-3AL)	3T	3.5T

1/ T = Thickness of material. Example: A piece of 0.040 MIL-T-9046, Type II, Composition A, would require a bend radii of 4 x 0.040 = 0.160 bend radii (minimum).

53450-2-2-T10

marked similarly to aluminum alloy sheet (see fig. 7). The metal is marked with a continuous ink roll marker. The marking includes:

- The brand name or trade name
- Type of titanium
    - Type I (commercially pure)
    - Type II (alpha phase)
    - Type III (alpha-beta phase)
    - Type IV (beta phase)
- Composition (A through F denoting actual composition of the material)
- Previous heat-treatment
- Specification number

2-26. **Working Characteristics.** Although titanium presents no serious or complex problems during the working process, the characteristics of this metal should be thoroughly considered prior to the operations of shearing, forming, grinding, drilling, sawing, and nibbling. The methods you employ should insure proper fabrication and also prolong the life of the tools and machinery you use.

2-27. *Shearing.* Shearing is successfully applied to titanium and its alloys if knives are in perfect condition. Knife life is short, maintenance cost is high, and sheared and blanked edges are not satisfactory without further hand filing, machining, or belt sanding to remove shear cracks.

2-28. For gages up to about 0.040 inch, 0.010 inch removal is sufficient. For gages over 0.040 inch, 0.020 inch to 0.025 inch must be removed from the sheared edge. Particular attention must be paid to the sharpness of the shear knives; nicked knives are not used.

2-29. Straight shears are applicable in the conventional manner. Blanking and piercing dies (male and female) are comparable to those used on ¼-inch hard stainless steel. (Kirtsite blanking dies are not satisfactory.) Power contour shears, power roll shears, and unishears may be employed. Gages in excess of 0.080 inch require square shears for alloy and commercially pure titanium.

2-30. *Forming.* You can form the unalloyed titanium at room temperatures, using approximately the same procedures as those established for 18-8 stainless steel. The basic difficulties encountered are sheet thickness, property variations, and direction of grain flow. The above factors, combined with high yield strength, high tensile strength, and low uniform elongation of commercial titanium alloys, makes forming difficult. The equipment current available was designed for material of uniform quality, and considerable work is required for adaptation to titanium.

2-31. Straightedge bending of titanium using a power brake or hand-forming equipment may be accomplished to a limited degree using the methods developed for stainless steel. Compensation for springback and the bend radii are the factors which require control. Springback is comparable to that of hard stainless steel when formed at room temperature. The bend radii will depend on the type of alloy and whether forming is done hot or cold. The forming material requiring tight bends or small radii necessitates the application of heat in the range of 500° Fahrenheit. The heat will only be applied for short periods of time to avoid excessive oxygen and nitrogen contamination which causes embrittlement. For approximate cold bend radii of sheet titanium, see table 10. Practice may reveal that smaller bend radii can be used.

2-32. *Grinding.* Titanium and its alloys are ground at approximately the same rate of speed as hardened high-speed steels and die steels. Moderately light cuts are recommended (periodic dressing is required to keep the wheel in proper condition). The frequency of dressing depends upon grinding conditions. Excessive wheel loading is likely to result in poor grinding action with subsequent poor surface finish, high residual tensile stresses, and low grinding ratios.

2-33. Wheel wear can occur in different ways with different results: by attrition, causing flat spots in individual grains; by grain fractures which expose new and sharp cutting points and edges; and by bond fracture which causes abrasive grains, individual or in clusters, to leave the wheel. These phenomena occur regardless of the material ground, and the relative amount of each contributing factor depends on grinding conditions and the material itself. Wear by attrition that is associated with titanium's chemical reaction toward abrasives becomes excessive only when titanium is ground improperly.

2-34. Loading, a phenomenon by which a metal being ground is deposited on or between the abrasive grains or both, can occur whether the wheel is sharp or dull. Dulling will intensify the loading process, for as loading continues, the grinding action decreases until burnishing occurs. The grinding temperature rises, causing high residual stresses in the ground surface, and results generally in an unsatisfactory surface finish.

2-35. Titanium can crack when ground under the same conditions normally used for steels. Under proper grinding conditions for titanium, however, grinding cracks no longer appear to be the problem they were when alloys were not of the present high quality and contained an excessive amount of hydrogen. Also, when etching solutions that contain hydrofluoric acid in the presence of insufficient nitric acid are used to

TOOL MATERIALS	1. Cobalt high-speed steels recommended for general use, deep holes, and sheet. 2. Molybdenum high-speed steels recommended for hand drilling sheet. 3. Carbides recommended for deep holes (when cost is justified as in long runs).
TYPE	1. Heavy-duty stub-type screw machine drills are recommended. 2. Fast spiral drills require less torque but may fail because of chipping. 3. Crank shaft, notch-type drills can be used on large sizes. 4. Large flutes reduce the tendency for chips to clog drill. 5. Use drills no longer than required for the desired depth but long enough for unrestricted chip flow through the flutes. Long, flexible drills produce out of round holes.
PRELIMINARY PREPARATIONS	1. Check drills received from crib for recommended drill pitch (geometry). When necessary regrind accurately on drill grinder and recheck the point angle, relief angle, and web thickness for correct values. 2. Chromium plating or an oxide treatment of the flutes may minimize alloying of chips to the flutes.
RECONDITIONING	Resharpening of the point alone is not always adequate. Recondition the entire drill and maintain current drill geometry.

53450-2-1-56

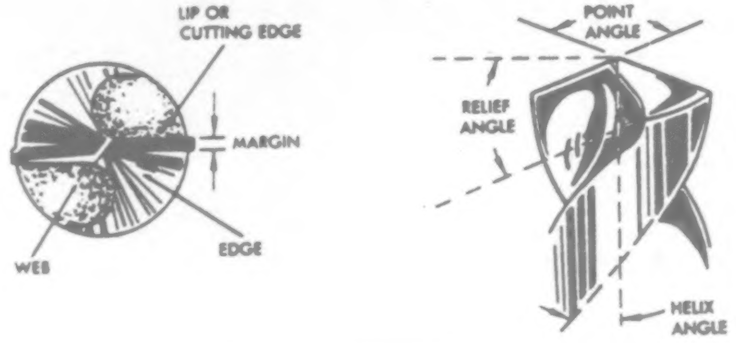
Figure 8. Titanium drilling procedures.

		High-Speed Steel				
		Cobalt Types			Moly Type, M–10	Carbides C–1, C–2
		T–4, T–5	T–5	T–4, T–5		
Design	Drill Diameter (inches)	General	Deep Holes	Sheet	Hand-Drilling Sheet	Deep Holes
Point Angle[a] (degrees)	¼-½	90 or double angle	90	135	150	Single-lip gun drill
	¼	140	140	118	–	
Helix Angle (degrees)	All	28–35	28–35	15	15	–
Relief Angle[b] (degrees)	All	9–12	9–12	12–15	Clearance with support	6–8
Cutting Angle (degrees)	All	–	–	–	Zero	–
Web[c]	All	–	–	Thin to ½ thickness	Thin to Center	–
Body Clearance	¼-½	–	–	Yes	No	–

(a) Point angles have a marked effect on drill life.
Try 90°, 118°, and 140° to determine the point angle best suited for the job. Blunt points are usually superior on small-size drills; 90 degrees or double angle (140° or 118° + 90° chamfer) seem best on the larger sizes.

(b) Relief angles are also important to drill life. Small angles tend to cause excessive pickup of titanium; too large angles weaken the cutting edges.

(c) When thinning the web be sure not to alter the effective rake angle.



53450-2-1-57

Figure 9. Titanium drill nomenclature and design.

reveal cracks, cracks may form if sufficiently high tensile stresses are initially present in the surface.

2-36. Grinding difficulties can be minimized by employing the proper type wheels at low wheel speed and feeds, and by flooding the grinding area with an inhibitor or purging type of cutting fluid. Grinding temperature must be kept low to keep stresses low.

2-37. *Drilling*. Titanium and its alloys may be difficult to drill unless certain procedures are followed. The galling action between titanium and tool materials, accentuated by high cutting temperatures, results in a rapid dulling of the cutting lips of the drill, which in turn produces poor cutting action and unsatisfactory holes.

2-38. A sharp cutting drill produces tight curling chips and no drilling difficulty. As the drill becomes dull, the cutting temperatures rise and the metal begins to smear to the lips and margins of the bits. Chip flow becomes increasingly difficult as temperatures rise. The appearance of feathered chips from the flutes indicates that the drill has become too dull for further use and should be sharpened or replaced. The appearance of irregular and discolored chips indicates that the drill has failed.

2-39. Drilling difficulties can be reduced by designing holes so they are as shallow as possible; by using short, sharp drills of approved design; by using cutting fluids so it will penetrate to the contact areas for maximum cooling; and by using low speeds and heavy feeds.

2-40. When improper drilling methods are used, out of round, tapered, or smeared holes occur. To prevent or minimize these difficulties, use sharp, clean drills of recommended material, size, and geometry; operate under appropriate cutting procedures, and holes produced will be of proper size and quality. (See figs. 8 and 9.) Careful handling of titanium parts is essential. Avoid scratches and nicks on all titanium parts, both around the drill press and in transit.

2-41. *Sawing*. Power hack saws, band saws, and friction saws are used for sawing titanium and its alloys. AMS 4908 alloy can be band-sawed successfully by using a standard ½-inch-wide blade having 10 teeth per inch traveling at a speed of about 2500 feet per minute. Constant

TABLE 11

SOLUTION HEAT-TREATING SCHEDULE

Material	Heat Treating Temperature (°F)		Soaking Time[a] (Minutes)	
	Sheet, strip and plate	Bars and forgings	Sheet, strip and plate	Bars and forgings
ALPHA-BETA ALLOYS				
8Mn	Not recommended	---	---	---
2Fe-2Cr-2Mo	1400 to 1480, incl	1400 to 1480, incl	30 to 60	30 to 60
2.5Al-16V	1360 to 1400, incl	1425 to 1450, incl	10 to 30	30 to 60
4Al-4Mn	1420 to 1480, incl	1420 to 1480, incl	15 to 30	60 to 120
4Al-3Mo-1V	1620 to 1660, incl	1700 to 1750, incl	10 to 30	60 to 120
5Al-1.5Fe-1.4Cr-1.2 Mo	1650 to 1700, incl	1650 to 1700, incl	15 to 30	30 to 120
6Al-4V	1600 to 1725, incl	1675 to 1750, incl	5 to 30	15 to 60
6Al-4V (low O)	Not recommended	Not recommended	---	---
6Al-6V-2Sn	1600 to 1700, incl	1600 to 1700, incl	15 to 30	30 to 60
7Al-4Mo	1657 to 1775, incl	1657 to 1775, incl	30 to 90	30 to 120
BETA ALLOY				
3Al-13V-11Cr	1400 to 1500, incl[b]	1400 to 1500, incl[b]	15 to 30	30 to 60

53450-2-2-T11

Notes:

[a] Longer soaking times may be necessary for specific forgings. Shorter soaking times are satisfactory when soak time is accurately determined by thermocouples attached to the load. Soaking time should be measured from the time that all furnace control instruments indicate recovery to the minimum process range.

[b] Synonymous with annealing.

86

TABLE 12
MAXIMUM QUENCH DELAY (WROUGHT ALLOYS)

Nominal Thickness (inches)	Maximum Time (seconds)[b]	Notes:
Up to 0.091 incl	4	[a] Quench delay time should begin when the furnace door begins to open, and end when the last corner of the load is immersed in the water quench tank. The maximum quench delay time may be exceeded, with extremely large loads or long length, if performance tests indicate that all parts comply with all other requirements.
Over 0.091	7	[b] Shorter times than those shown may be necessary to ensure that the minimum requirements are complied with when quenched.

53450-2-2-T12

TABLE 13
AGING SCHEDULE

Material	Aging Temperature (°F)	Soaking Time (Hours)
ALPHA-BETA ALLOYS		
2Fe-2Cr-2Mo	900 to 950, incl	4 to 6
2.5Al-16V	960 to 990, incl	3 to 5
4Al-4Mn	875 to 950, incl	4 to 10
4Al-3Mo-1V	900 to 950, incl[a]	6 to 12[a]
5Al-1.5Fe-1.4Cr-1.2Mo	950 to 1050, incl	4 to 8
6Al-4V	920 to 1050, incl	4 to 6
6Al-6V-2Sn	875 to 1125, incl	4 to 8
7Al-4Mo	975 to 1200, incl	4 to 8
BETA ALLOY		
3Al-13V-11Cr	850 to 950, incl	2 to 60[b]

Notes:

53450-2-2-T13

[a] For an intermediate strength level, age at 1050 - 1150°F, inclusive for 1/6 to 6 hours, using shorter time at the higher temperature.

[b] Time depends on strength level desired.

97

rate of feed of about 25 feet per minute is necessary. Water-soluble coolants are desirable.

2-42. Friction sawing is readily accomplished, provided a positive feed is maintained and there is no interruption in the cut. A heavy burr is formed, proportional to the gage thickness, which must be draw filed or belt sanded to remove the ragged edges before forming to prevent the possibility of subsequent cracking.

2-43. *Nibbling*. Nibbling is sometimes used for titanium alloys. Short tool life and high maintenance costs are penalties that must be accepted for the convenience of this process.

2-44. **Marking Methods.** Commonly used marking methods are acceptable for titanium alloys, except those methods which physically damage the surface, such as impression stamps, scratch-awls, electric pencils, punch marks, etc. Good judgment is obviously required; for example, drilled holes for locating pins are universally punch-marked prior to drilling. However, layout line intersections for location of parts are not punched.

2-45. Stencils are standard practice for denoting directional properties of sheets by orienting stencil codes parallel to rolling directions. Stencils must be removed, however, prior to stress relieving, or damage occurs from etch effects during the heat-treatment.

2-46. **Heat-Treatment.** The requirements for control of heat-treating processes, as applied to titanium and titanium alloys manufacturing and maintenance facilities, are covered by specification MIL–H–81200, Heat Treatment of Titanium and Titanium Alloys. Generally, the purpose of heat-treating is to obtain desired properties within the limitation of the respective titanium and titanium alloy. Mandatory temperatures and soaking times specified for the various heat-treatments (solution, aging, stress relief, and annealing; tables 11 through 16) to cover the various parts, thicknesses, sizes, and shapes for all materials of titanium and titanium alloys cannot be stated. Temperature and time will vary due to those factors. The temperature and time ranges recommended are adjustable to develop the desired properties of titanium and titanium alloys which are specified in the related procurement documents for titanium materials, or detailed in applicable drawings and purchase orders.

2-47. *Furnaces*. Titanium and its alloys react with the elements hydrogen, oxygen, nitrogen, and carbon which alone or in combination act to embrittle the metal. Hence, titanium materials, particularly at heat-treating temperatures, must be

TABLE 14

COMPLEX ANNEALING SCHEDULE

Material	Annealing Temperature (°F)	Treating Time (Hours)
	8Al-1Mo-1V	
Sheet-single annealed condition	1435 to 1465, incl[a]	1 to 8
Sheet-duplex annealed condition[c]	1435 to 1465, incl[a]	1 to 8
	followed by	
	1435 to 1465, incl[b]	1/4 to 1
Bar and forging-duplex annealed	1650 to 1850, incl	3/4 to 1-1/4
	followed by	
	1000 to 1125, incl[d]	8 to 24

53450-2-2-T14

Notes:

[a] Furnace cooled to 700°F, then air cooled.

[b] Air cooled.

[c] For good creep resistance combined with high toughness.

[d] For minimum distortion 1650 to 1675°F, 50 to 65 minutes, followed by 1100 to 1125°F, 7 to 9 hours. For high creep resistance 1825 to 1850°F, 50 to 65 minutes, followed by 1100 to 1125°F, 7 to 9 hours.

TABLE 15
STRESS RELIEF SCHEDULE

Material	Stress Relief Temperature (°F)	Stress Relief Time (Hours)
UNALLOYED (COMMERCIALLY PURE)		
	1000 to 1100, incl	1/3 to 2/3
	975 to 1000, incl	1/2 to 1
	880 to 925, incl	2 to 4
	780 to 825, incl	7 to 8
ALPHA ALLOYS		
5Al-2.5Sn	1175 to 1200, incl	1/4 to 1/2
	1090 to 1125, incl	3/4 to 2
	990 to 1025, incl	4 to 6
5Al-2.5Sn(low 0)	1175 to 1200, incl	1/4 to 1/2
	1090 to 1125, incl	3/4 to 2
	990 to 1025, incl	4 to 6
5Al-5Sn-5Zr	1100 to 1150, incl	1/2 to 3/4
7Al-12Zr	975 to 1200, incl	1/4 to 1
7Al-2Cb-1Ta	1000 to 1200, incl	1/4 to 1
8Al-1Mo-1V	1075 to 1125, incl[a]	3/4 to 1-1/4
	1300 to 1450, incl[b]	1/6 to 1/2
ALPHA-BETA ALLOYS		
8Mn	900 to 1100, incl	1/2 to 2
2Fe-2Cr-2Mo[a]	900 to 1000, incl	1/2 to 1
2.5Al-16V	1360 to 1450, incl[a]	1/4 to 2
4Al-4Mn	1250 to 1350, incl	1/2 to 2-1/2[d]
4Al-3Mo-1V	900 to 1100, incl	1/2 to 8
5Al-1.5Fe-1.4Cr-1.2Mo	1100 to 1200, incl	1/2 to 2
6Al-4V[f]	900 to 1200, incl	1/2 to 50
6Al-4V(low 0)[e]	900 to 1200, incl	1/2 to 50
6Al-6V-2Sn	1000 to 1100, incl	1/2 to 3
7Al-4Mo	900 to 1300, incl[f]	1/2 to 8
BETA ALLOY		
3Al-13V-11Cr[g]	900 to 1000, incl	1/4 to 60

Notes:

[a] Stress relief depends upon annealing cycle employed. For single annealed sheet, see table 14.

[b] Stress relief for duplex annealed sheet (see table 14).

[c] Same as solution treatment (see table 11).

[d] Furnace cooling.

[e] For 100 percent relief, 1000°F - 50 hours, or 1200°F - 5 hours. For 50 percent relief, 1000°F - 5 hours, or 1100°F - 1/2 hour.

[f] Use highest practical temperature.

[g] During aging. If aging not employed, heat treat at 1050 to 1100°F for 1/2 to 2 hours. Solution for aging (see table 11) may be synonomous with stress relief annealing for this alloy.

53450-2-2-T15

TABLE 16
ANNEALING SCHEDULE

Material	Annealing Temperature (°F)	Time (Hours)
UNALLOYED		
99.5Ti[a]	1000 to 1300, incl	1/2 to 2
99.2Ti[a]	1000 to 1300, incl	1/2 to 2
99.1Ti[a]	1000 to 1300, incl	1/2 to 2
99.0Ti[a]	1000 to 1300, incl	1/2 to 2
98.9Ti[a]	1000 to 1300, incl	1/2 to 2
0.15 to 0.20 Pd[a]	1000 to 1300, incl	1/2 to 2
ALPHA ALLOYS		
5Al-2.5Sn[a]	1325 to 1550, incl	1/4 to 4
5Al-2.5Sn(low 0)[a]	1325 to 1550, incl	1/4 to 4
5Al-5Sn-5Zr	1630 to 1670, incl	1/4 to 1
7Al-12Zr[b]	1630 to 1670, incl	1/4 to 1
7Al-2Cb-1Ta	1630 to 1670, incl	1/4 to 1
8Al-1Mo-1V[c]	1430 to 1470, incl	8
ALPHA-BETA ALLOYS		
8Mn[d]	1250 to 1300, incl	1
2Fe-2Cr-2Mo[a]	1175 to 1200, incl	1/2
2.5Al-16V[e]	1360 to 1450, incl	1/6 to 1/2
4Al-4Mn[d, f]	1250 to 1300, incl	2 to 24
4Al-3Mo-1V[d]	1225 to 1250, incl	2 to 4
5Al-1.5Fe-1.4Cr-1.2Mo[a]	1180 to 1200, incl	4 to 24
6Al-4V[d, g]	1275 to 1550, incl	1/2 to 8
6Al-4V(low 0)[d, g]	1275 to 1550, incl	1/2 to 8
6Al-6V-2Sn[a]	1300 to 1500, incl	2 to 3
7Al-4Mo[d, h]	1425 to 1450, incl	1-8
BETA ALLOY		
3Al-13V-11Cr[e]	1430 to 1470, incl	1/4 to 1

Notes:

[a] Air cooled.

[b] This heat treatment may be used for sheet and plate. For bar and forgings, heat treat at 1275° to 1325°F for 3/4 to 1 hour, followed by air cooling.

[c] For sheet. For bar and forgings, anneal 1650° to 1850°F for 1 hour, with a water quench or air cooling, followed by heating at 1050 to 1100°F for 8 hours with air cooling. See table 14 for annealing condition to increase toughness and creep resistance.

[d] Slow cooling to 1000° to 1050°F, maximum in furnace at a rate of not greater than 300°F per hour.

[e] Solution treatment (see table 11) is suggested for annealing.

[f] For maximum formability, heat treat for 24 hours.

[g] For sheet, heat treatment 1300° to 1350°F, 1 hour, cooled at a rate of not greater than 50°F per hour maximum to 300°F maximum. Air cooling may be used for lower ductility requirements. For bar and forging, heat treat at 1275° to 1325°F, for 2 hours and air cool. For hydrogen removal by vacuum annealing, heat treatment at 1300° to 1500°F, for 1/2 to 2 hours, then furnace cool to 1100°F maximum.

[h] This is for maximum formability. For maximum creep proportion, heat treat after the annealing treatment for 24 hours at 1000° to 1050°F.

53450-2-2-T16

kept out of contact with materials or atmospheres containing appreciable amounts of these elements. For low-temperature heat-treatments, air chamber furnaces are more flexible and more econical for handling large volumes of work. At high temperatures, where surface oxidation becomes significant, a muffle furnace using external heating offers more protection, particularly if the furnace is gas-fired. Electric furnaces for small lots or special heat-treatments are preferred, since heating can be accomplished internally or externally with a minimum of contamination.

2-48. *Solution heat-treatment.* The time to heat required to bring about the required degree of solid solution increases with increasing thickness of the section. The minimum soaking period is determined by testing samples to make certain that the required mechanical properties have been developed. The soaking periods shown in table 11 are representative of commercial practice.

2-49. The soaking period for titanium products should be the minimum necessary to develop the required mechanical properties. Longer soaking periods may cause oxygen, hydrogen, and nitrogen to diffuse into the titanium alloy. Nitrogen, like oxygen, is soluble in both the alpha and beta phases of titanium, although more extensively in the alpha phase than in the beta phase. Oxygen and nitrogen contamination during heat-treating results in a brittle skin, introducing difficulties in further forming operations. Hydrogen absorption on heating may lead to hydrogen embrittlement.

2-50. *Heat-treating temperatures.* In general, the heat-treatment selected for the alpha-beta and the beta alloys are designed to provide the best combination of strength, ductility, and toughness. If the specified maximum temperature is exceeded, there is a danger of heating over the beta transus temperature, with subsequent impairment of the mechanical properties of the alloys. Scaling of titanium and titanium alloys starts at about 1100° Fahrenheit. Heating above 1100° Fahrenheit under oxidizing conditions results in increasingly severe surface-scaling, as well as diffusion of oxygen. Oxygen diffusion results in a hard, brittle surface layer. This layer must be removed by mechanical or chemical means prior to forming parts, or application in stressed components. If the temperature is below the minimum specified, complete solution is not effected and the optimum mechanical properties are not developed.

2-51. *Quenching.* On the alpha-beta alloys, a rapid quenching after solution-treating is necessary to obtain the maximum mechanical properties. Rapid quenching deters formation of grain-boundary alpha on slow cooling which adversely affects the mechanical properties.

2-52. *Hydrogen embrittlement.* Hydrogen embrittlement presents a major problem with titanium and its alloys. Hydrogen is readily absorbed from pickling or scale removal baths, and the atmosphere at elevated temperatures during heat-treatment. Hydrogen embrittlement in commercially pure titanium and the alpha alloys results in a reduction in ductility and slight increase in strength. A decrease in impact strength below 200° Fahrenheit and a shift in the temperature range, where the change from ductile to brittle behaviour occurs, is also observed. For the alpha-beta alloys, embrittlement is found at slow speeds of testing and under constant or "sustained" loads. Quenching and aging to high-strength levels increases the sensitivity of alpha-beta alloys to hydrogen embrittlement compared to the low strength alpha-beta annealed condition.

2-53. *Annealing stability.* In the alpha-beta titanium alloys, thermal stability is a function of the beta-phase transformation. In cooling from annealing temperatures (see table 16), beta may transform and under certain conditions (such as fast cooling), and in certain alloys (such as 8Mn, 4A1–4Mn, 4A1–3M0–1V, and 7A1–4M0), may form the brittle omega phase. The slow-cooling stabilizing-anneal is designed to produce a stable beta capable of resisting further transformation when exposed to elevated temperatures.

2-54. *Stress corrosion.* Titanium alloys are susceptible to stress corrosion by dry sodium chloride at temperatures above 600° Fahrenheit. For this reason, care is taken to insure proper cleanliness (i.e., absence of salt, and in particular, fingerprints) on parts to be heat-treated or used above 600° Fahrenheit.

2-55. **Cleaning.** The importance of cleaning as a material preparation requirement is underestimated. Cleaning processes which have been developed for unalloyed titanium apply to the alloyed titanium sheet stock. Heavy oxides formed on the surface of commercially pure sheet, usually at temperatures in excess of 1000° Fahrenheit, can be removed by one of several tried processes.

2-56. Grease, oil, dirt, and scale may be removed by solvent degreasing, chemical pickling, grit blasting, grinding, wire brushing, or a combination of these treatments. Solvent degreasing may be accomplished using hot trichloroethylene at 180° Fahrenheit. Either wet or dry grit blasting may be used. The pickling solution recommended is a mixture of 20 to 30 percent nitric acid and 2 percent hydrofluoric acid by volume mixed in water. Precautions must be taken to keep the nitric acid content from dropping below its normal range, since a nitric content below 10 percent will result in hydrogen embrittlement.

2-57. **Ordering Titanium.** Requisitioning or ordering of titanium differs but slightly from aluminum which we covered previously. When looking up class codes we find titanium sheet to be 9535, and then C9500–IL–AF as further identification. Insure that the specification is identified in table 337 or 338. Table 337 covers titanium alloys, while table 338 covers the commercially pure forms of titanium sheet.

2-58. Once the particular specification is found and the material is identified by Federal stock number, consider size of the material. Sheets run in widths of 36 to 48 inches and lengths from 74 to 144 inches. The titanium material identified has additional information on the particular type, composition of material (shown in table 9) and the surface finish of the sheet.

2-59. After the Federal stock number has been established, the routine continues as with aluminum; we go to the C9500–ML–AF and identify the Federal stock number with the pertinent information needed to procure the material on DD Form 1348, as shown in figure 5.

2-60. Storage of titanium and titanium alloy sheets is similar to that of aluminum. No oiling is necessary, but to prevent accidental scratching of the surface, separate or interleave between each sheet with heavy paper. The environmental aspects of storage are the same for all metals in storage. They should be stored in an enclosed space away from windows and doors and in a position to eliminate, as much as possible, humidity-inducing environments: steam pipes, heating systems, etc. In storage, metals are separated from metals of different compositions (steels, aluminums, titanium, and magnesium).

2-61. **Inspection of Titanium Repairs.** Repairs that have been made with materials containing either titanium or titanium alloy deserve more than casual attention before approval. All of the general practices of repairs—strength, weight, resistance to corrosion, and contour—must be checked, besides areas specifically vulnerable because of the nature of the material itself. Some persons have the tendency to expect the repair to suffice whether properly accomplished or not because of the reputation of titanium itself.

2-63. Possibly while under fabrication, the metal was improperly marked and was scratched, or the sheared or punched edges of the metal had not been properly trimmed or finished. Previous discussion shows that hand filing or sanding is required to eliminate cracks in the metal. Improper riveting of the material will create stresses to the metal that will cause failure of the repair. Last and most important is that titanium's outstanding features lead to the tendency of "overusing" this material when it is not recommended by the aircraft manufacturer or applicable technical orders, and the dissimilar metals could cause more problems by being used and being stronger than the original.

2-63. Now turn to the workbook and answer the exercises for this section.

3. Steels

3-1. Until about the middle of the 18th century, steel in its present state was practically unknown, although materials having its general properties, such as the famous Damascus and Toledo sword blades, had been in use for hundreds of years. Where then did steel come from as know it today?

3-2. It was not until the process of separating the slag (impurities) from wrought iron by using high temperatures was developed that steel as we know it could be manufactured. The first forms of alloying iron with other minerals was very tedious. By packing those carefully made blades in charcoal, bone ash, or some other carbon bearing material and heating to a temperature above 1400° Fahrenheit, carbon could be diffused into the iron, creating a steel. By technological advancement in creating higher temperatures and through experiment with various metals, many different types of steels have been developed and are in daily use in aircraft construction and repair.

3-3. If carbon is added to iron, in percentages ranging up to approximately 1.00 percent, the product is vastly superior to iron alone and is classified as carbon steel. Carbon steel forms the base of those alloy steels produced by combining carbon steel with other elements known to improve the properties of steel. A base metal (such as iron) to which small quantities of other metals have been added is called an alloy. The addition of other metals changes or improves the physical properties of the base metal for a particular use.

3-4. **Identification.** With the many different types and alloys of steels available today, you will need to know how they are identified. Manufacturers identify their metals and alloys using numbers and letters. With the coming of the industrial age, the demand for different types of steels needed by others—not just the metal manufacturers—demanded a set of standardized names, numbers, and specifications within the metal area. SAE (Society of Automotive Engineers) developed through the cooperation of metal manufacturers and users of metal a set of standardized steel classifications.

3-5. *Society of Automotive Engineers numbering.* The steel classification of the SAE is used in specifications for all high grade steels used in

TABLE 17
SAE NUMERICAL INDEX

Type of steel	Classification
Carbon	1xxx
Nickel	2xxx
Nickel-chromium	3xxx
Molybdenum	4xxx
Chromium	5xxx
Chromium-vanadium	6xxx
Tungsten	7xxx
Silicon-manganese	9xxx

53450-2-2-T17

automotive and aircraft construction. A numerical index system identifies the composition of SAE steels.

3-6. Each SAE number consists of a group of digits. The first represents the type of steel; the second indicates the percentage of the principal alloying element; and usually the last two or three digits designate the percentage in hundredths of 1 percent of carbon in the alloy. For example: The SAE number 4150 indicates a molybdenum steel containing 1 percent molybdenum and 0.50 percent carbon. Use table 17 for reference to the index system.

3-7. *Color coding.* As with aluminum, a color code system has been developed to identify steels that are less than ½ inch in diameter: bars, tubing, etc. Table 18 shows the SAE color coding for steel. Convert colors to numbers using this table; for example: A piece of steel marked with colored 5-inch-wide stripes of black and white and a narrow 2-inch stripe of black will identify the material as 4130 steel. 1020 steel would be marked wide red stripe and narrow yellow stripe.

3-8. *Metal marking.* Iron or steel products are marked in similar fashion to aluminum marking. The metal is marked with a continuous ink roll marker. Marking symbols on sheet, tubing, and bar stock include the producer's name or trademark, specification or commercial designation. and the heat-treatment designation.

3-9. All plates, sheets, and strips 1 inch or more in width are marked in rows at intervals of at least 3 feet for the length of the product. The printing in adjacent rows is alternately staggered. Numbers of rows are determined by the width of the product as follows:

For corrosion and heat-resistant and alloy steel:

- 12 inches or less—not less than one row.
- Over 12 inches to 24 inches—not less than two rows.
- Over 24 inches to 36 inches—not less than three rows.
- Over 36 inches to 48 inches—not less than four rows.
- Over 48 inches—an additional row for every 12 inches.

For carbon and high-strength, low-alloy steels:

- 24 inches or less—not less than one row.
- 24 to 48 inches—not less than two rows.
- Over 48 inches—not less than three rows.

3-10. All tubular products ¼ inch or more in outside diameter are marked in constantly recurring symbols at intervals of not greater than 3 feet throughout the length of the product.

TABLE 18
COLOR CODING FOR STEEL

BROAD STRIPE (5 inches)

Color	First digits of steel-numbers
Red	10
Red and Yellow	13
Yellow	23
Yellow and Green	25
Green	31
Green and White	40
Black and White	41
Blue and White	43
Red and Black	46
White	61
Black and Yellow	86
Black and Green	87

NARROW STRIPE (2 inches)

Color	Last two digits of steel-numbers
Red and Black	00
Red	10
Red and Green	12
Red and White	15
Yellow	20
Yellow and White	25
Black	30
Black and White	35
Green	40
Green and White	45
Blue	50
Blue and Brown	55
Brown	60
Brown and White	65
Olive Drab (Khaki)	95

3-11. **Methods of Identification.** As with aluminum and titanium, your ability as an airframe repairman to recognize or identify steels as to their hardness and physical properties prior to use is very important from the aspect of strength, safety, and corrosion. The methods of checking hardness are similar to those mentioned earlier, with the addition of the spark test for ferrous metals.

3-12. *Brinell testing.* The application and use of the Brinell tester is similar to the application with aluminum except for preparation of the material and the load applied.

3-13. In the preparation of steels, the sample piece must be free of all scratches and other variations that will affect the reading of the tester. This can be done by filing, grinding, and polishing the sample.

3-14. Previously we mentioned the application of the load to the sample. A load of 3,000 kilograms is required for steel, compared to the 500-kilogram load being used for the softer metals, such as aluminum, copper, brass, and bronze. Normally you should apply the load to the sample for 30 seconds, although this period may be increased to 1 minute for extremely hard steels to produce equilibrium. Then release the pressure and measure the area of impression with the calibrated microscope as with aluminum.

3-15. *Rockwell testing.* The Rockwell testing procedures are similar to those used with aluminum, as you use an indentor/penetrator of either diamond or a hardened steel ball. The diamond indentor called a "brale" is precision-ground and polishes, and the shape is spheroconical (both spherical and cone shaped, like a single dip ice cream cone). The steel ball normally used on steel is $\frac{1}{16}$-inch diameter, whereas ⅛-, ¼-, or ½-inch balls are used on aluminum. The size of the ball is determined by the hardness range of the type of material to be tested. It is not our intention here to elaborate on the different scales and tables used to determine the hardness of any specific metal or alloy. Any additional information needed for identifying specific material may be obtained in TO 1-1A-9, *Aerospace Metals —General Data and Usage Factors.*

3-16. *Spark testing.* Spark testing is a common means of identifying various ferrous metals which have become mixed together in a scrap pile. In this test, the piece of iron or steel is held against a revolving grinding stone and the metal is identified by the sparks thrown off. Each ferrous metal has its own peculiar spark characteristics. The spark streams vary from a few tiny shafts to a shower of sparks several feet in length. Few nonferrous metals, except titanium, give off sparks when touched to a moving grinding stone. Therefore, these metals cannot be successfully identified by the spark test.

3-17. Wrought iron produces long shafts that are straw colored as they leave the stone and white at the end. Cast iron sparks are red as they leave the stone and turn to straw color. Low carbon steels give off long straight shafts having a few white sprigs. As the carbon content of the steel increases, the number of the sprigs along each shaft increases and the stream becomes white in color. Nickel steel causes the spark stream to contain small white blocks of light within the main burst.

3-18. **Types, Characteristics, and Uses of Alloyed Steels.** While steel of the plain carbon type remains the principal product of the steel mills, so-called alloy or special steels are being turned out in ever-increasing tonnage. As an airframe repairman, you will have contact with these metals in day-by-day working on aircraft, so let us consider those alloyed steels generally used in aircraft and their uses.

3-19. *Carbon steels.* Steel containing carbon in percentages ranging from 0.10 to 0.30 percent is classed as low carbon steel. The equivalent SAE numbers range from 1010 to 1030. Steels of this grade are used for making such items as safety wire, certain nuts, cable bushings, and threaded rod ends. This steel in sheet form is used for secondary structural parts and clamps, and in tubular form for moderately stressed structural parts.

3-20. Steel containing carbon in percentages ranging from 0.31 to 0.50 percent is classed as medium carbon steel. This grade of steel is especially adaptable for machining or forging, and where surface hardness is desirable. Certain rod ends and light forgings are made from SAE 1035 steel.

3-21. Steel containing carbon in percentages ranging from 0.51 to 1.05 percent is classed as high carbon steel. The addition of other elements in varying quantities adds to the hardness of this steel. In the fully heat-treated condition, it is very hard, will withstand high shear and wear, and will have little deformation. It is limited in aircraft. SAE 1095 in sheet form is used for making flat springs and in wire form for making coil springs.

3-22. *Nickel steels.* The various nickel steels are produced by combining nickel with carbon steel. Steels containing from 3 to 3.75 percent nickel are commonly used. Nickel increases the hardness, tensile strength, and elastic limit of steel without appreciably decreasing the ductility; it also intensifies the hardening effect of heat-treatment. SAE 2330 steel is used extensively for aircraft parts such as bolts, terminals, keys, clevises, and pins.

3-23. *Chrome-nickel or stainless steels.* These are corrosion-resisting metals. The anticorrosive degree of this steel is determined by the surface condition of the metal as well as by the composition, temperature, and concentration of the corrosive agent.

3-24. The principal alloy of stainless steel is chromium. The corrosion-resisting steel most often used in aircraft is known as 18-8 steel because of its content of 18 percent chromium and 8 percent nickel. One of the distinctive features of 18-8 steel is that its strength may be increased by cold-working. This metal is also known by several different trade names, such as Carpenter's Stainless Steel, Resistal KA2, 18-8 Enduro, and Allegheny Metal.

3-25. Stainless steel may be rolled, drawn, bent, or formed to almost any shape. Because these steels expand about 50 percent more than mild steel and conduct heat only about 40 percent as rapidly, they are more difficult to weld. Stainless steel, with a slight variation in its chemical composition, can be used on almost any part of an aircraft. Some of its common applications are in the fabrication of exhaust collectors, stacks and manifolds, structural and machined parts, springs, castings, tie rods, and cables.

3-26. *Chrome-vanadium steels.* These are made of approximately 18 percent vanadium and about 1 percent chromium. When heat-treated, they have strength, toughness, and resistance to wear and fatigue. A special grade of this steel in sheet form can be cold-formed into intricate shapes. It can be folded and flattened without signs of breaking or failure. SAE 6150 is used for making springs; and chrome vanadium with high carbon content, SAE 6195, is used for ball and roller bearings.

3-27. *Chrome-molybdenum steels.* Molybdenum in small percentages is used in combination with chromium to form chrome-molybdenum steel which has various uses on aircraft. Molybdenum is a strong alloying element. It raises the ultimate strength of steel without affecting ductility or workability. Molybdenum steels are tough and wear-resistant, and they harden throughout from heat-treatment. They are especially adaptable for welding, and for this reason they are used principally for welded structural parts and assemblies.

3-28. This type steel has practically replaced carbon steel in the fabrication of fuselage tubing, engine mounts, landing gears, and other structural parts. For example, a heat-treated SAE 4130 tube is approximately four times as strong as an SAE 1025 tube of the same weight and size.

3-29. The popular series of chrome-molybdenum steel is that series containing 0.25 to 0.55 percent carbon, 0.15 to 0.25 percent molybdenum, and 0.50 to 1.10 percent chromium. These steels, when suitably heat-treated, are deep hardening, easily machined, readily welded by either gas or electric methods, and are especially adapted to high temperature service.

3-30. *Inconel.* Inconel is a nickel-chromium-iron alloy closely resembling stainless steel in appearance. Because these two metals look very much alike, a distinguishing test is often necessary. One method of identification is to use a solution of 10 grams of cupric chloride in 100 cubic centimeters of hydrochloric acid. With a medicine dropper, place 1 drop of the solution on the sample of each metal to be tested and allow it to remain for 2 minutes. At the end of this period, slowly add 3 or 4 drops of water to the solution on the metal samples, 1 drop at a time; then wash the samples in clear water and dry them. If the metal is stainless steel, the copper in the cupric chloride solution will be deposited on the metal leaving a copper-colored spot. If the sample is inconel, a new looking spot will be present.

3-31. The tensile strength of inconel is 100,000 pounds per square inch, annealed, and 125,000 pounds per square inch, hard-rolled. It is highly resistant to salt water and well able to withstand temperatures as high as 1600° Fahrenheit. Inconel welds readily and has working qualities quite similar to those of corrosion-resistant steels.

3-32. *General.* The progress of aviation has been aided by continuous research in metallurgy. This research has brought forth alloys to withstand the high temperatures and velocities encountered in jet and rocket-powered units. These alloys are chemically similar to the previously mentioned steels but may also contain cobalt, copper, and columbium in varied amounts as alloying elements.

3-33. **Principles of Heat-Treatment.** Previously we discussed the term "heat-treatment" as it applies to aluminum. Remember that with aluminum alloys the term means heating, soaking, and quenching and that there are only two reasons for heat-treatment of aluminum, those of hardening and annealing. The term "heat-treatment" when applied to steels, takes on several other meanings beyond those of heating, soaking, and quenching although those three factors are sometimes present. The other processes involved are hardening, tempering (drawing), annealing, normalizing, and carburizing (cementation).

3-34. ***Hardening.*** At ordinary temperatures, the carbon content of steel exists in the form of particles of iron carbide scattered throughout the iron matrix (foundation). The nature of these carbide particles, their number, size, and distribution, determines the hardness and strength of the steel. At elevated temperatures, the carbon is dissolved in the iron matrix and the carbide particles appear only after the steel has cooled through its "critical temperature" (explained in the next paragraph). If the rate of cooling is slow, the carbide particles are relatively coarse and few. In this condition, the steel is soft. If the cooling is rapid, as with quenching in oil or water, the carbon precipitates as a cloud of very fine carbide particles. This condition is associated with high hardness of the steel.

3-35. At elevated temperatures, the iron matrix exists in a form called "austenite," which is capable of dissolving carbon in solid solution. At ordinary temperatures, the iron exists as "ferrite," in which carbon is relatively insoluble and precipitates, as described in the preceding paragraph, in the form of carbide particles. The temperature at which this change from austenite to ferrite begins to occur on cooling is called the "upper critical temperature" of the steel. This upper critical temperature varies with the carbon content up to approximately 0.85 percent carbon. The upper critical temperature is lowered with increasing carbon content. From 0.85 to 1.70 percent carbon the upper critical temperature is raised with increasing carbon content. Steel that has been heated to its upper critical point will harden completely if rapidly quenched; however, in practice it is necessary to exceed this temperature by approximately 50° to 100° Fahrenheit to insure thorough heating of the inside of the piece. If the upper critical temperature is exceeded too much, an unsatisfactory coarse grain size will be developed in the hardened steel.

3-36. Successful hardening of steel will largely depend upon the following factors after a steel has been selected which has hardening ability:

- Control over the rate of heating, specifically to prevent cracking of thick and irregular sections.
- Thorough and uniform heating through sections to correct hardening temperatures.
- Control of furnace atmosphere, in the case of certain steel parts, to prevent scaling and decarburization.
- Correct heat capacity, viscosity, and temperature of quenching medium to harden adequately and to avoid cracks.

NOTE: The thickness of the section controls the depth of hardness for a given steel composition. Very thick sections may not harden through because of the low rate of cooling at the center.

3-37. When heating steel, the temperature should be determined by the use of accurate instruments. At times, however, such instruments are not available, and in such cases, the temperature of the steel may be judged by its color. The accuracy with which temperatures may be judged by color depends on experience, the light in which the work is being done, the character of the scale on the steel, the amount of radiated light within the furnace, and the emissivity or tendency of steel to radiate or emit light.

3-38. *Quenching procedures.* A number of liquids may be used for quenching steel. Both the medium and the form of the bath depend largely on the nature of the work to be cooled. It is important that a sufficient quantity of the medium be provided to allow the metal to be quenched without causing an appreciable change in the temperature of the bath.

3-39. The tendency of steel to warp and crack during the quenching process is difficult to overcome. Warping and cracking usually occur when certain parts of the article cool more rapidly than others. Whenever the rate of cooling is not uniform, internal stresses are set up on the metal which result in warpage or cracking. Operations such as forging and machining may set up internal stresses in steel parts and it is therefore advisable to normalize articles before attempting the hardening process. The following procedures greatly reduce the warping tendency and should be carefully observed:

a. An article should never be thrown into quenching media or bath. By permitting it to lie on the bottom of the bath, it is apt to cool faster on the top side than on the bottom side, thus causing it to warp or crack.

b. The article should be slightly agitated in the bath to destroy the coating of vapor which might prevent it from cooling rapidly. This allows the bath to remove the heat of the article rapidly by conduction.

c. An article should be quenched in such a manner that all parts will be cooled uniformly and with the least possible distortion.

d. Irregularly shaped sections should be immersed in such a manner that the parts of the greatest section thickness enter the bath first.

3-40. *Quenching medium.* Oil is much slower in action than water, and the tendency of heated steel to warp and crack when quenched may be greatly reduced by its use. Parts made from high carbon steel will not develop maximum hardness when quenched in oil unless they are quite thin in cross section. In aircraft metal. oil is generally used and is recommended in all cases where it will produce the desired degree of hardness.

NOTE: Alloy steels should never be quenched in water.

3-41. In certain cases water is used in the quenching of steel for the hardening process. The water bath should be approximately 65° Fahrenheit, as extremely cold water is apt to warp or crack the steel and water above this temperature will not produce the required hardness.

3-42. A 10 percent salt brine (sodium chloride) solution is used when higher cooling rates are desired. A 10 percent salt brine solution is made by dissolving 0.89 pound of salt per gallon of water.

3-43. For some articles, a bath of water covered by a film of oil is occasionally used. When the steel is plunged through this oil film a thin coating will adhere to it, retarding the cooling effect of the water slightly, thus reducing the tendency to crack due to contraction.

3-44. You should straighten warped parts, by first heating to below the tempering temperature of the article, and then applying pressure. This pressure should be continued until the piece is cooled. Retemper the part after straightening at the straightening temperature. No attempt should be made to straighten hardened steel without heating, regardless of the number of times it has been previously heated, as steel in its hardened condition cannot be bent or sprung cold, with any degree of safety.

3-45. *Tempering (drawing).* Steel that has been hardened by rapid cooling from a point slightly above its critical range is often harder than necessary and generally too brittle for most purposes. In addition, it is under severe internal stress. In order to relieve the stresses and reduce the brittleness or restore ductility, the metal is always "tempered." Tempering consists in reheating the steel to a temperature below the critical range (usually in the neighborhood of 600 to 1200° Fahrenheit). This reheating causes a coalescence and enlargement of the fine carbide particles produced by drastic quenching, and thus tends to soften the metal. The strength needed will determine the tempering temperature. This is accomplished in the same types of furnaces used for hardening and annealing.

3-46. As in the case of hardening, tempering temperatures may be approximately determined by color. These colors appear only on the surface and are due to a thin film of oxide which forms on the metal after the temperature reaches about 450° Fahrenheit. In order to see the tempering colors, the surface must be brightened. A buff stick consisting of a piece of wood with emery cloth attached is ordinarily used for this purpose. Although the color method is convenient, it should not be used unless adequate facilities for determining temperature are not obtainable. The most desirable method for general aeronautical use is to determine temperatures by hardness checks, and to make subsequent adjustments as necessary to obtain the properties required. For recommended tempering temperatures for specific metals, see the heat-treat data for material and composition in Technical Order 1–1A–9.

3-47. *Annealing.* Steel is usually subjected to the annealing process to increase its ductility by reducing hardness and brittleness, and to refine the crystalline structure and remove stresses. Steel which has been cold-worked is usually annealed to increase its ductility and soften the material prior to machining and forming.

3-48. *Normalizing.* Although normalizing involves a slightly different heat-treatment, it may be classed as a form of annealing. This process also removes stresses due to machining, forging, bending, and welding. Normalizing may be done in furnaces used for annealing. The articles are put in the furnace and heated to a point approximately 150° to 225° Fahrenheit above the critical temperature of the steel. After the parts have been held at this temperature for a sufficient time to be heated uniformly throughout, they must be removed from the furnace and cooled in still air. Prolonged soaking of the metal at high temperatures must be avoided, as this practice will cause the grain structure to enlarge. The length of time required for the soaking temperature will depend upon the mass of metal being treated.

3-49. *Case hardening.* In many instances it is desirable to produce a hard, wear-resistant surface or "case" over a strong, tough core. Treatment of this kind is known as case hardening, and may be done in several ways, the principal ways being carburizing and nitriding.

3-50. Surface hardening or softening by applying intense heat (such as that produced by an Oxy-Acetylene flame) can be accomplished on almost any of the medium carbon or alloys steel; i.e., 1040, 1045, 1137, 1140, etc. The parts are surface hardened by applying a reducing flame (an oxidizing flame should never be used) at such a rate that the surface is rapidly heated to the proper quenching temperature for the steel being treated. Following the application of the heat, the part is quenched by spraying water or oil rapidly. The fast quench hardens the steel to the depth that the hardening temperature has penetrated below the surface. The actual hardness resulting will depend on the rate of cooling from the quenching temperature. In hardening by this method, the shape and size or mass of the part must be considered. Most operations will require special adapted spray nozzles to apply the quenching agent, which is usually water. Normally, flame hardening will produce surface hardness higher than can be obtained by routine furnace heating and quenching, because the surface can be cooled at a faster rate. If a combination of high strength core and surface is required, some of the medium carbon alloy steels can be heat-treated and subsequently surface hardened by the flame method. This method is ideal for hardening noncritical items such as bucking bars, but is not adapted for surface hardening of parts for use in critical applications.

3-51. Surface softening is accomplished by heating the surface to just below the temperature required for hardening and allowing the material to cool naturally (in air). This method is sometimes used to soften material that has been hardened by flame cutting.

3-52. The induction method of heating can be used to surface harden steels, in a manner similar to that used for flame hardening. The exception is that the heat for hardening is produced by placing the part in a magnetic field (electrical) specifically designed for the purpose.

3-53. In some instances, the induction method can be used to deep harden; the extent will depend on the exposure and dwell time, intensity of the magnetic field, and the size of the part to be treated.

3-54. *Carburizing*. At elevated temperatures iron reacts with gaseous carbon compounds to form iron carbide. By heating steel, while in contact with a carbonaceous substance, carbonic gases given off by this material will penetrate the steel to an amount proportional to the temperature of heating. For example, if mild or soft steel is heated to 1350° Fahrenheit in an atmosphere of carbonic gases, it will absorb carbon from the gas until a carbon content of approximately 0.80 percent has been attained at the surface, this being the saturation point of the steel for the particular temperature. By increasing the heat to 1650° Fahrenheit, the same steel will absorb carbon from the gas until a carbon content of approximately 1.1 percent has been attained, which is the saturation point for the increased temperature.

3-55. The carburizing process may be applied to both plain carbon and alloy steels, provided they are within the low carbon range. Specifically, the carburizing steels are those containing not more than 0.20 percent carbon. The lower the carbon content in the steel, the more readily it will absorb carbon during the carburizing process.

3-56. The amount of carbon absorbed and the thickness of the case obtained increases with time; however, the carburization progresses more slowly as the carbon content increases during the process. The length of time required to produce the desired degree of carburization depends on the material used and the temperature to which the metal is subjected. In carburizing, carbon travels slowly from the outside toward the inside center, and, therefore, the proportion of carbon absorbed must decrease from the outside to the inside.

3-57. The simplest method of carburizing consists of soaking the parts at an elevated temperature while they are in contact with solid carbonaceous material such as wood charcoal, bone charcoal, and charred leather.

3-58. Liquid carburizing consists of immersing the parts in a liquid salt bath, heated to the proper temperature. The carbon penetrates the steel as in the solid method, producing the desired case.

3-59. Gas carburizing consists of heating the parts in a retort and subjecting them to a carbonaceous gas such as carbon monoxide or the common fuel gases. This process is particularly adaptable to certain engine parts.

3-60. When pack carburizing, you pack the parts with carburizing material in a sealed steel container to prevent the solid carburizing compound from burning and to retain the carbon monoxide and dioxide gases. Nichrome boxes, capped pipes or mild steel, or welded mild steel boxes may be used. Nichrome boxes are most economical for production because they withstand oxidation. Capped pipes of mild steel or welded mild steel boxes are useful only as a substitute. The container should be so placed as to allow the heat to circulate entirely around it. The furnace must be brought to the carburizing temperature as quickly as possible and held at this heat from 1 to 16 hours, depending upon the depth of the case desired and the size of the work. After carburizing, the container should be removed and allowed to cool in air, or the parts should be removed from the carburizing compound and quenched in oil or water.

3-61. Carburized steel parts are rarely used without subsequent heat-treatment, which consists of several steps to obtain optimum hardness in the case and optimum strength and ductility in the core. Grain size of the core and case is refined.

3-62. The core is refined by reheating the parts to a point just above the critical temperature of the steel. After soaking for a sufficient time to insure uniform heating, the parts are quenched in oil.

3-63. The hardening temperature for the high carbon case is well below that of the core. It is, therefore, necessary to heat the parts again to the critical temperature of the case and to quench them in oil to produce the required hardness. A soaking period of 10 minutes is generally sufficient.

3-64. Stress relieving is necessary to minimize the hardening stresses produced by the previous treatment. The stress-relieving temperature is generally around 350° Fahrenheit. This is accomplished by heating, soaking until uniformly heated, and cooling in still air. When extreme hardness is desired, the temperature must be carefully held to the lower limit of the range.

3-65. *Nitriding.* This method of case hardening is advantageous because it results in a harder case than is obtained by carburizing. Nitriding is generally applied to certain special steel alloys, one of the essential constituents of which is aluminum. The process involves exposing the parts to ammonia gas or other nitrogenous material for 20 to 100 hours at 950° Fahrenheit. The container in which the work and ammonia gas are brought in contact must be airtight and capable of maintaining good circulation and even temperature throughout. The depth of the case obtained by nitriding is about 0.015 inch if heated for 50 hours. The nitriding process does not affect the physical state of the core if the preceding tempering temperature was 950° Fahrenheit or over. Nitrided surfaces can be reheated to 950° Fahrenheit without losing any of their hardness; however, if heated above that temperature, the hardness is rapidly lost and cannot be regained by retreatment. Prior to any nitriding treatment, all decarburized metal must be removed to prevent flaking of the nitrided case. When no distortion is permissable in the nitrided part, it is necessary to normalize the steel prior to nitriding to remove all strains resulting from the forging, quenching, or machining.

3-66. **Heat-Treating Equipment.** Equipment necessary for heat-treating steel consists of a suitable means for bringing the metal to the required temperature, of a measuring and controlling device, and of a quenching medium. Heat may, in some instances, be supplied by means of a forge or welding torch; however, for the treatment required in aircraft work, a furnace is necessary. Various jigs and fixtures are sometimes needed for controlling quenching and preventing warpage.

3-67. *Heat-treating furnaces and baths.* The acceptable methods for heat-treating steels are the same as those for aluminum. They include the use of air, combusted gases, protective atmosphere, inert atmosphere or vacuum furnaces, molten-fused salt baths, and molten-lead baths. The heat-treating furnaces or baths are of many designs, and no one size or type suffices for every heat-treating requirement. Protective and inert atmospheres are utilized and circulated as necessary to protect all surfaces of parts comprising the furnace load.

3-68. The heating equipment must be so designed and constructed that the furnace or bath is capable of maintaining within the working zones, at any point, a temperature varying no more than ±25° Fahrenheit from the required heat-treating temperature, with any charge. After the charge has been brought up to treating or soaking temperature, all areas of the working zone must be within the permissible temperature range specified for the steel or alloy being heat-treated.

3-69. *Quenching tanks and liquids.* As with aluminum, suitable tanks must be provided for steel quenching baths. The tanks should be large enough to allow the liquids to remain approximately at room temperature. Circulating pumps and coolers are used for maintaining approximately constant temperatures where a large amount of quenching is done. The location of of these tanks is very important, because insufficiently rapid transfer from the furnace to the quenching medium may destroy the effects of the heat-treatment in many instances.

3-70. The quenching liquids commonly used for steels are: water at 65° Fahrenheit, commercial quenching oil, and fish oil.

3-71. **Corrosion Resistance.** We will discuss corrosion prevention and identification later in this course, but right now we need to find out how the characteristics of iron and steel affect the corrosion resistance of the metal itself.

3-72. Generally, most metals and alloys must be properly heat-treated to derive the maximum corrosion resistance benefits from alloying. For example, the steels containing carbon are usually quenched and tempered to provide the desired corrosion-resistant properties, and stainless steels are more resistant in the annealed condition and must be properly treated to resist intergranular corrosion.

3-73. The different structures in an alloy may promote corrosion under some conditions. When the degree of difference is such that localized areas possess electrical potentials different from the remainder of the material, anode and cathode areas will exist.

3-74. Under specific environmental conditions, a stressed metal will corrode more rapidly then one that is unstressed. Residual or applied tensile stresses in a metal can lead to severe localized corrosion and spontaneous cracking of the metal.

3-75. *Susceptibility to corrosion.* The susceptibility to corrosion of a metal or an alloy varies with the environment or conditions of exposure to which it is subjected. Mild or aggressive atmospheres or waters may be involved. Further, the method of processing a metal (whether cast or forged; its design, shape, or contour; its combination with other metals in the structure in which it is used) influences its behavior under corrosive conditions.

3-76. Alloys of a metal very likely will exhibit different corrosion characteristics than the pure parent metal; frequently, but not in all cases, they are more resistant to corrosion. Therefore, for the purposes of this course, the discussion of corrosiveness of any one metal and its alloys will be general.

3-77. Basically, two chemical substances are responsible for the corrosion of iron and its alloys, namely oxygen and water; but other corrosive agents and environmental conditions such as acidic vapors, salts, alternate wetting and drying, and high-temperature conditions accelerate the attack.

3-78. Ferrous alloys corrode quite differently in industrial, marine, and rural atmospheres. Atmospheric corrosion will vary with the composition and concentration of moisture. Corrosion rates are lowest in dry, uncontaminated atmospheres. Industrial atmospheres, because they usually contain some sulfur dioxide, acid vapors, and salts, may result in rapid attack of the metal. In marine environments, particularly because of condensate and spray, the corrosion rate of iron alloys can be quite severe.

3-79. *Corrosion-resistant steels.* Iron-base alloys containing 12 percent or more chromium (as well as other constituents) are the stainless steels. They are remarkably resistant to corrosion because chromium content in excess of 12 percent fosters the development of passivity (protective-film formation on the metallic surface) and imparts a grain structure that contributes to corrosion resistance. The use of these steels is governed by the oxidizing characteristics of the service environment. Where strong oxidizing conditions exist, stainless steels are superior to the more noble metals and alloys. But they are vulnerable to acidic reducing agents.

3-80. The stainless steels and other corrosion-resistant ferrous alloys exhibit superior resistance to general or uniform attack, pitting, intergranular attack, erosion-corrosion, and other forms of localized attack arising from contact between the alloy and another metal or nonmetallic surface. Not all the compositions are equally resistant under all conditions. Resistance increases with increasing amount of chromium and decreases with higher carbon content. The actual behavior is exceedingly complex. For example, passivity, an important factor in the corrosion resistance of stainless steels, is not a constant state but exists only under certain conditions. The steels become "passive" and resistant under oxidizing conditions but behave as "active" in the presence of reducing agents that inhibit film formation. Active stainless steels are listed just below ordinary steel in the galvanic series; the passive stainless steels are listed just above silver.

3-81. Almost all stainless steels require suitable heat-treatment to develop maximum corrosion resistance. The steels containing carbon are usually quenched and tempered to provide optimum resistance to corrosion, and normally they show maximum resistance in the fully hardened condition. Relief of quenching stresses, coupled with greatly improved ductility and toughness, may be obtained by tempering these steels at 700° Fahrenheit, or less, without seriously reducing their resistance to atmospheric corrosion. However, tempering between 700° and 1100° Fahrenheit should be avoided, particularly when the carbon content is high, since this range of temperature imparts low toughness as well as low resistance to corrosion. The austenitic stainless steels are more resistant in the annealed condition. These steels, with the exception of the stabilized alloys 321 and 347, are rendered susceptible to intergranular corrosion when heated in the range of 750° to 1650° Fahrenheit, or on cooling slowly through this range. Steels so sensitized are vulnerable to severe attack at the grain boundaries even by relatively mild corrosive agents. This same condition is developed when these steels are welded. Resistance may be improved by annealing at about 2000° Fahrenheit, followed by rapid cooling (water quenching), removal of the oxide scale, and repassivation. The stabilized alloys 321 and 347 are not subject to sensitization.

3-82. The characteristics of the corrosive environments and the requirements of the application should be carefully evaluated when you specify a particular composition. The complexity of the problem is selecting the correct alloy makes it necessary for the airframe repairman to consult the available data. This data should be used only as a guide. In many instances, the selection of a stainless steel must be based on experience and tests under actual operating conditions.

3-83. **Working Steels.** You, as an airframe repairman, must be well trained in the fundamentals of metal forming practices, corrosion control, heat-treating, riveting, blueprint reading, and assembly. You must keep constantly abreast of advancing processes for maximum efficiency and proficiency. The selection of steel for design or application to equipment and components is usually based on the following:

- Strength and weight requirement of the part or equipment to be fabricated.
- Method of fabrication; i.e., welding, forming, machining, heat-treatment, etc.
- Corrosion resistance to certain chemicals or environments.
- Temperatures to which parts will be subjected.
- Fatigue properties under cyclic loads.

3-84. The following general rules are employed in handling and forming steel materials:

a. Sheet, sheared or sawed strips and blanks should be handled with care to prevent cutting your hands and other parts of your body.

b. Sheared or cut edges must be sanded, filed, or polished prior to forming. Rough and sharp edges should be removed before other machining operations are started, in order to reduce hazards in handling.

c. Form material across the grain when possible, using correct or specified bend radii. Also provide bend relief holes in corners when required.

d. Observe load capacity of equipment such as brakes, presses, rolls, drills, shears, etc.

CAUTION: Machines rated for carbon steel must not be used over 60 percent of rated capacity when cutting or forming stainless steel unless approved by responsible technical authority. *When in doubt, inquire.*

e. Tools and equipment must be smooth, free of nicks, rust, burrs, and foreign material. In addition, dies must be checked for alignment tolerances.

f. Surfaces of material, especially finished sheet, should be protected from scratching, foreign particles, etc. These surfaces can be protected by using noncorrosive paper, tape, other approved material, and good cleaning procedures.

g. Polished sheet material must be protected during forming to prevent die tool marking.

CAUTION: Avoid handling parts, especially corrosion-resistant steel, with bare hands after cleaning and subsequent to heat-treating or passivation, because fingerprints will cause carburization and pitting of the surface when the part is heated.

3-85. **Working Stainless Steels.** The working of stainless steels is similar to the working of other metals. You must take special precautions cutting, drilling, bending, and punching. The pressure required for working stainless compared to mild steel is about doubled. The corrosion-resisting steels, especially the 18-8 grades, are more difficult to work than the carbon steels and other metals. Even though they are difficult to work, the same general methods are used with modification or compensation for the individual characteristics of each type or grade.

3-86. *Drilling corrosion-resisting steel.* High-speed drills are commonly used for drilling stainless steel. Special types are used for drilling grades 420, 440, etc., that are abrasive due to high carbon content. Speeds for drilling the high carbon types are usually reduced 25 to 50 percent in comparison with the other grades.

3-87. Drills for use with the corrosion-resisting steels are prepared with different cutting angles than are used with carbon steel. Drill points or tips for use with the chromium-nickel grades are ground with 135°–140° (included angle) and 8° to 15° lip clearance. The webb support for the point should be as heavy as possible; however, thinning of the webb at the point will relieve point pressure. When you drill the free machining 400 series grades, reduce the angle to 118° to 130° included angle.

3-88. When you drill the corrosion-resisting steels, you should control the speed to prevent hardening of metal and excessive drill damage from heat. For suggested drilling speed using high speed drill bits, see table 19.

3-89. Lubrication for drilling stainless is recommended using soluble oil for general and light drilling and sulphurized mineral or fatty oils for heavy work. It is extremely important to use adequate lubrication or coolant in drilling stainless steel because of its poor heat conduction.

3-90. *Reaming corrosion-resisting steel.* The recommended reamer for the corrosion-resisting steels is the spiral fluted type made from high-speed steel, and carbide tipped. These special fluted reamers are used to help alleviate chatter and chip removal that are associated with the straight fluted reamers.

TABLE 19

DRILLING SPEEDS FOR CORROSION-RESISTING STEELS

GRADE TYPE	SPEED SFPM (APPROX)
301, 302, 304, 310	20 - 40
303	40 - 80
309, 316, 321, 347	30 - 50
403, 410	35 - 75
416, 420F, 430F	60 - 95
420 AB & C	20 - 40
442, 446	30 - 60

53450-2-2-T19

3-91. Due to the work-hardening characteristics of the corrosion-resisting steel, leave sufficient stock to insure that cutting will be behind the work-hardening surface resulting from drilling.

3-92. Reamers for cutting stainless steel should have a 26° to 30° starting chamfer, with a slight lead angle behind the chamfer of 1° to 2° for about ⅛ to 3/16 inch on the land to reduce initial shock of cutting. The land should be ground with a clearance of 4° to 7° (and width should not be reduced below 0.010 to 0.012 inch) to reduce rubbing and frictional heat.

3-93. Speeds for reaming will vary according to type of material being cut. The recommended speed for reaming types 301, 302, 304, 316, 321, 347, 403, and 410 is 20 to 75 surface feet per minute; for 430F, 420F, 416, 440F, and 303, 35 to 100 surface feet per minute. Trial should be conducted to determine best cutting speeds for individual operations.

3-94. *Sawing.* Hack saws (hand) for cutting corrosion-resisting steel should be of high speed steel with approximately 32 teeth per inch for light work and approximately 24 teeth per inch for heavy work. The teeth area should be of wavy construction to increase width of the cut area to prevent binding. To prevent work-hardening, the blade should not be allowed to drag or ride on the return stroke, especially with the 300 series types. The hack saw blade should be lightly lubricated with lard oil or other cutting oil for best results.

3-95. Hack saws (mechanical drive) are used for heavy cross-cutting section bars, tubing, etc. With the power hack saw, deeper cuts are made at relatively low speed. The deeper cuts are used to get under work-hardened surface resulting from the previous cut (stroke). The teeth per inch for saw blades averages 8 to 12, and speed of saw travel usually ranges from 50 to 100 feet per minute, depending on the type and temper of the material being cut. Coolant or lubrication is essential to prevent excess blade damage from heat. Lubrication recommended is soluble oil and water (about one part oil to four parts water for heavy work); and for light work, a light grade cutting oil.

3-96. Band sawing is well suited for low speed (straight line or contour) sawing of stainless or corrosive-resisting steel within prescribed limitations. The saw manufacturer's recommendations must be followed for cutting speed, saw selections, etc. Speeds usually vary with the physical properties, temper, etc., of type or grade being cut. As a general guide, speeds range from 100 to 125 feet per minute for material under 0.062 and 60 to 100 feet per minute for thickness over 0.062 inch. Saw blades must be sharp for effective low-speed sawing.

3-97. For faster cutting with the band saw, the friction cutting method may be employed. In using the friction method, the band saw velocity ranges from 5000 feet per minute for cutting flat 1/32-inch material to about 10,000 feet per minute for ½-inch and 14,000 for 1-inch material. Tubing material is run at slightly higher speed. Feed for this material can be considerably higher than is used for slow-speed cutting. Rates range from about 100 feet per minute for light gage to 15 to 18 feet per minute for ½-inch material.

3-98. Heavy pressure to maintain cut is not usually necessary. Pressure should be just sufficient to create proper heating and softening at cut point without forcing the saw. Lubricants should not be used.

3-99. *Bending (single curvature).* Most steel sheet can be bent, provided that equipment with

TABLE 20

COLD BEND RADII (INSIDE) CARBON/LOW ALLOY STEELS

Temper, Sheet Thickness = T (Inches).									
Alloy Temper	0.016	0.020	0.025	0.032	0.040	0.050	0.063	0.125	0.187
1020/1025	2T	2T	2T	2T	2T	2T	2T	2T	2T
4130 Annealed	2T	3T	2 1/2T	2T	2 1/2T	2T	2T	2T	2T
4130 Normalized	2T	3T	2 1/2T	3T	3T	3T	3T	3T	3T
8630 Annealed	3T	3T	2 1/2T	3T	2 1/2T	2T	2T	2T	2T
8630 Normalized	3T	3T	2 1/2T	3T	3T	3T	3T	3T	3T

53450-2-2-T20

TABLE 21

COLD BEND RADII (INSIDE) CORROSION-RESISTANT STEEL ALLOYS

Sheet Thickness = T (Inches).				
Alloy	**Temper**	**0.012 - 0.051**	**0.051 - 0.090**	**0.190 - 0.250**
201, 202	Annealed	1-2T	1T	1 1/2T
301, 302	1/4 Hard	1-2T	1 1/2T	2T
305, 304	1/2 Hard	2T	2T	2T
309, 310	3/4 Hard	2T	3T	--
316, 321, 347	Hard	3-4T	4-5T	--
405, 410, 430	Annealed	1T	1T	1 1/2T
17-7PH	Annealed	1T	1 1/2T	2T

53450-2-2-T21

adequate bending and cutting capacity is available and if the materials are formed in the soft condition or lower temper range. The heat-treatable alloys are usually formed in the annealed condition and heat-treated if required or specified after forming. Some difficulty will be encountered from warping due to heat-treating and precautions must be taken when forming the material to prevent sporadic or uneven stress in the work piece. Parts will require jigs or close control during the heating and cooling phase of heat-treatment. Thus, heat-treated formed sheet metal parts are seldom used on aerospace craft. Most materials are used in the normalized or annealed condition.

3-100. Springback allowances vary according to the type and temper of material being formed. The use of sharp bend radii on parts should be avoided when the parts are subject to flexing (cycle) or concentrated stresses, due to possible fatigue or stress-corrosion failure. For recommended general bend radii for use on aircraft, see table 20 for low carbon and low alloy steel and table 21 for corrosion-resistant steel.

3-101. In using table 20 and table 21, it is recommended that in practice the bend area be checked for strain, grain, or bend cracking. If parts show presence of these, increase the radius by one thickness or more until the difficulty is remedied.

3-102. *Shearing.* To prevent damage to shear and to assure clean, accurate cuts, clearance between shear blades should be approximately 1/20 of the thickness of the material to be cut. Blades or knives must be maintained in sharp condition, clean and free of nicks. Where only one shear is available, a clearance of 0.005 to 0.006 inch could be used for general shearing of sheet stock up to 0.125 inch thick. Excessive blade clearance must be avoided to prevent working hardening of cut area which increases susceptibility to stress corrosion and burring. Lubrication such as light weight engine oil or soap should be applied at regular intervals to prevent galling and to clean blades for prolonged shear blade life.

3-103. *Blanking and punching.* Blanking and punching requires close control of die clearance, shearing action of the punch or blanking die. Clearance for blanking and punching should be 5 percent of the thickness and closely controlled for all gages. Punches and dies should be maintained in clean, sharp condition and lubricated by swabbing or spraying the material to be punched with light weight lube oil to prevent galling and to aid in keeping the punch and die clean.

3-104. *Forming sheet stock.* The corrosion-resisting series, types 301, 302, 304, 410, 430, 431, etc., generally have good forming and drawing qualities. Some types (302, 304, and 305) have forming characteristics superior to plain carbon steel because of the wide spread between tensile and yield strength, and higher elongation. More power is required to form these types than is required for carbon steel because of higher tensile strengths; and their yield strength increases rapidly during forming and bending.

3-105. The straight chromium grades, such as 410, 416, 430, and 446, react similarly to carbon steel and are somewhat less ductile than the 300 series stainless steel. The tensile strengths are higher than that of carbon steel and consequently will stand higher loads before rupture. Yield strengths are also higher, which means that more power is required for bending and forming.

3-106. The strains set up by severe reductions (above 45 percent with chromium-nickel types and 20 percent with straight chromium types) should be relieved by annealing immediately after the operation is completed, especially if you are using type 301. If this material is not relieved in 2 to 4 hours, it may crack.

3-107. Springback allowance should be about two to three times the amount allowed for carbon steel, and naturally will vary according to the type of material being formed. Sharp radii must be avoided where parts are subjected to flexing or to concentrated stresses caused by possible fatigue or stress corrosion failure. Recommended bend radii for use with stainless steel are shown in table 21.

3-108. *Hot-forming.* Hot-forming is used to form shapes in stainless that cannot be achieved by cold-forming. In using heat for forming, it is important that temperature be closely controlled. Finished parts should be relieved of residual stress and carbide precipitation which affects corrosion resistance. In either case, this is accomplished by fully annealing.

3-109. Hot-forming is done at somewhat lower temperatures. The unstabilized chromium-nickel grades may be formed at temperatures up to 800° Fahrenheit and the extra low carbon grades up to 1000° Fahrenheit. The use of temperatures higher than those cited above should be avoided to prevent subjection of the material to carbide precipitation.

3-110. The straight chromium (type 400 series) steels are more responsive to hot-forming than the chromium-nickel grades. The reaction of these metals to hot-forming is similar to carbon steels. Upon heating to 800° to 900° Fahrenheit, their tensile strength is lowered considerably and at the same time ductility begins to increase. The air-hardening grades, types 403 and 410, are formed in two temperature ranges:

(1) Low temperature forming up to 1400° Fahrenheit. The advantage of forming at this temperature is that parts can be stress-relieved at 1350° to 1450° Fahrenheit to restore strength uniformity, and scaling is held at a minimum.

(2) High temperature forming at 1525° to 1575° Fahrenheit. At this temperature forming is somewhat easier because strength is low and ductility is higher. Upon completion of forming at this temperature, parts must be fully annealed under controlled conditions by heating to 1550° Fahrenheit and holding, slowly cooling to 1100° Fahrenheit (at approximately 50° Fahrenheit per hour) and then cooling in air.

3-111. **Requisitioning Steel.** When you requisition steel, the procedures are but slightly different from ordering aluminum and titanium and we have discussed these procedures. When you look up class codes, you look for steel sheet, knowing that in this particular case you are looking for stainless, corrosion-resistant sheet. In the alphabetical index of the H2-3, we find that steel sheets are cross-referenced to be in class 9515. Going to the C9500-IL-AF, we find that corrosion-resisting steel sheet is found in table 127, identified as MIL-S-5059, Composition 301. This material is intended for use in fabrication of the structural parts of aircraft where corrosion-resistant steel is required but where gas or arc welding and elevated temperatures are not involved.

3-112. Once the particular specification is found and the material is identified as to thickness, width, and length, additional information is to be found on this particular table as to the surface finish, bright or dull, and the temper condition—whether the metal is in the annealed or hard condition. Identify the particular piece of material you need by the Federal Stock number.

3-113. After the Federal Stock Number has been identified, requisitioning is the same as that for aluminum and titanium: turn to the C9500-ML-AF and identify the Federal Stock Number with the information needed to procure the material on a DD Form 1348 as shown in figure 5.

3-114. **Storage.** The storage of steel and steel alloys is similar to the storage of aluminum and titanium. One of the major factors to be considered in the storage of steels is the surface finish. It is important to prevent marring or scratching of the material and to prevent corrosion due to different compositions of metal coming in contact. All materials when stored must be separated by inserting paper between each two sheets of metal. As with aluminum and titanium, humidity inducing environments such as doors, windows, steam pipes, and heating systems must be avoided for storage areas as much as possible. Steels when stored should be in an enclosed area to prevent contamination and injury to the material. A suitable rack will prevent injury to the material and make each piece of material readily identifiable as well.

3-115. **Inspection of Steel Repairs.** Steel repairs, upon completion, must be inspected to insure proper procedures have been followed during fabrication. You must ascertain that all of the general rules of strength, weight, and contour, as well as the rules involving dissimilar metals, have been complied with. Steel should only be fastened with steel parts: rivets, bolts, etc. The appropriate –3 technical order will specify if steel is allowed in areas other than those originally containing steel. In some instances, damages to an aluminum area may be repaired using steel pieces and parts, but the technical order is the final word on such repairs. Previously we mentioned the cracking of steel while being bent, burrs being removed after drilling, and edges of the metal being smooth. All of these factors, plus the proper installation of fasteners (rivets and bolts, etc.), are major items you should check before you approve a finished steel repair.

3-116. Before continuing to the next section, turn to the workbook and answer exercises for Section 3.

4. Magnesium

4-1. Magnesium, the world's lightest structural metal, is a silvery-white material weighing only about two-thirds as much as aluminum. Where does it come from?

4-2. Magnesium is probably more widely distributed in nature than any other metal. It can be obtained from such ores as dolomite and magnesite, from underground brines, from waste liquors of potash, and from sea water. With 10 million pounds of magnesium in 1 cubic mile of sea water, there is no danger of a dwindling supply.

4-3. Magnesium is produced today in the United States from three primary sources.

(1) Magnesium chloride and carnallite, derived either from salt deposits found in the vicinity of Midland, Michigan, or from sea water taken from the ocean near Freeport, Texas.

(2) Magnesite and dolomite, both of which are found in relatively large deposits in the states of Washington, California, and Nevada.

(3) Brucite, with extensive deposits in at least 12 states.

4-4. As a general rule, the ores contain relatively small percentages of magnesium, and must first be concentrated. The naturally occurring minerals contain water of crystallization which must be eliminated before reduction processes can begin.

4-5. **Identification.** Magnesium alloys produced in the United States consist of magnesium alloyed with varying proportions of aluminum, manganese, and zinc. These alloys are designated by a letter of the alphabet with the number 1 indicating a high purity and maximum corrosion resistance.

4-6. Many of the magnesium alloys manufactured in this country are produced by the Dow Chemical Company and have been given the trade name of Dowmetal Alloys. To distinguish between these alloys each is assigned a letter. Thus, we have Dowmetal J, Dowmetal M, and so forth.

4-7. Another manufacturer of magnesium is the American Magnesium Corporation, a subsidiary of the Aluminum Company of America. Their alloys are designated in the same manner as aluminum alloys. Thus, we have 265, which represents a casting alloy, and 3S, 57S, and so forth, which indicate wrought alloys.

4-8. *Metal marking.* Shipping containers are marked as indicated in the individual metal's specification. In general, each container has the following designations: alloy, specification, size, or form, quantity, contractor's name, and other pertinent information as required by the specification. The different forms of the material are marked as indicated:

(1) Castings are identified with the pattern or part number, by the use of raised numerals. They may be stamped with symbols to indicate heat-treatment and aging.

(2) Forgings are identified with the part number by the use of raised numerals.

(3) Extrusions are marked with the manufacturer's trademark and specification along the full length at intervals of 2 feet or less, with paint, marking fluid, or other means.

(4) Sheet is marked with the specification, manufacturer's trademark, thickness, and composition in rows of recurring symbols from edge to edge, with a suitable marking fluid.

4-9. *Chemical.* If the identification markings have been obliterated, you can distinguish magnesium from aluminum by means of a spot test. A one-half of one percent solution of silver nitrate in contact with a magnesium surface causes the metal to turn black, in sharp contrast to an aluminum surface which does not react to the solution. To make a spot test on an unknown alloy, you should first clean the surface of the metal with a file. It is important that the filing be deep enough to remove any paint or other surface coating to expose the base metal. Place a drop of silver nitrate solution on the cleaned surface. If the surface turns black, then the metal is magnesium; but if no reaction occurs, it is probably aluminum. This test merely identifies the metal as magnesium base alloy; the exact identity of the various compositions can only be determined by a chemical analysis. It should be noted that cadmium and zinc also react with silver nitrate, but since these metals would likely be present only as thin coatings, the deep filing would remove them.

4-10. **Types of Magnesium.** The metal is available in various compositions including the commercially pure (99.8 percent minimum), alloys for casting, and alloys for the manufacture of wrought products. Ordinarily, the compositions used for casting are different from those employed for rolling, forging, and other working. Substantially pure magnesium finds practically no use in aircraft design or for stressed parts.

4-11. *Casting alloys.* There are four groups of magnesium casting alloys. The first group is based on the Mg-Al binary (2 part) system and is subdivided into those alloys containing zinc and manganese. The second group is based primarily on the Mg-Zn binary system with zirconium additions. These two groups are valuable for their structural behavior at normal or slightly elevated temperatures of less than 300° Fahrenheit. The third group is based on the magnesium-rare earth-metal binary alloys, and the fourth on the Mg-Th binary system. The last two groups have been specifically designed for their strength at elevated temperatures of 500° to 800° Fahrenheit. Although some of these casting alloys have outstanding normal temperature properties, they are not competitive with alloys of the first two groups because of the higher cost of the alloying elements.

4-12. To improve the mechanical properties or stabilize dimensions of magnesium alloy sand and permanent mold castings, use heat-treatment, aging, solution heat-treatment, and solution treatment followed by aging.

4-13. *Wrought alloys.* There are many types of wrought products such as rolled sheet or plate, extrusion, and forgings. These worked forms have the advantage of lower cost, higher strengths, and ductilities, and have greater versatility of mechanical properties than cast forms. Magnesium is well adapted to all three working processes, especially extrusion.

4-14. *Designating system.* The ASTM (American Society for Testing Materials) nomenclature system is used exclusively in designating magnesium alloys. In this system, the first two letters indicate the principal alloy elements, while the numbers indicate the respective percentage. The letters are used to symbolize the following:

A—aluminum
E—rare earth metals (elements 57–60 or combinations)
H—thorium
K—zirconium
L—lithium
M—manganese
Q—silver
T—tin
Z—zinc

Suffix letters represent variations in composition. The use of X denotes that the alloy is experimental and is not yet adopted by ASTM.

4-15. **Characteristics.** When you select magnesium for a particular application, you must consider the intended use, service requirements, mechanical and physical properties of the alloys, form in which manufactured, and the proposed method of production of the part.

4-16. After you determine mechanical and physical requirements, the choice of an alloy should be made on the basis of which alloy will fulfill both the technical and economic requirements. In this connection, formability, corrosion resistance, adaptability to joining methods, and necessity for heat-treatment, as well as cost, must be considered.

4-17. *Casting alloys.* The choice of a casting composition is dictated largely by certain features of the design and cost, and the method of production. For magnesium alloys, the important casting processes are the same as with aluminum: sand, permanent, semipermanent mold, and die casting. The choice of a casting process depends upon the size and shape of the part, minimum section thickness, tolerances, and types of surface finish, as well as the number of pieces to be produced and the relative cost of finishing the parts.

4-18. *Wrought alloys.* The selection of a wrought magnesium alloy is influenced by the particular application and its requirements, type of wrought products, its mechanical properties, and fabricating characteristics.

4-19. Wrought forms of magnesium alloys, as used in Government specifications, include plate and sheet, and extrusions (bar, rod, shapes, and tube).

4-20. Magnesium alloy finds numerous applications. It may be readily drawn hot into various shapes. Extrusions have many uses, especially as components in structural assemblies. The extrusion process is unusually adaptable to the production of standard and special shapes in magnesium alloys.

4-21. *Forms available.* Magnesium alloys are available in all the usual metal forms including: ingots and billets; sand, permanent mold, and die castings; forgings; extruded bars, rods, shapes, and tube; and rolled sheet, plate, and strip.

4-22. *Physical properties.* Magnesium, in its pure state, has a specific gravity of 1.74, weighing .063 pound per cubic inch. The physical properties provide magnesium and its alloys with many distinctive and practical qualities wherever they are used.

4-23. The coefficient of thermal expansion of magnesium alloys is critical in the temperature

106

TABLE 22
ALLOY COMPOSITIONS AND SPECIFICATIONS

Comparative Specifications				Chemical Comp.			
USAF	DOW	MAZLO	ASTM	ALUM.	MANG.	ZINC	General Use
AN-M-16	R	AM-263	AZ-90	9.0	0.13	0.7	Die Castings
AN-M-20	J-1	AM-C57S	AZ-61x	6.5	0.15	1.0	Forgings
AN-M-21	0-1	AM-C58S	AZ-80x	8.5	0.12	0.5	Forgings
AN-M-22	M	AM-3S	M-1	-	1.50	-	Forgings
AN-M-23	-	AM-65S	AT-35	3.5	0.40	Tin 5.0	Forgings
AN-M-24	J-1	AM-C57S	AZ-61x	6.5	0.15	1.0	Bars, Shapes
AN-M-25	0-1	AM-C58S	AZ-80x	8.5	0.10	0.5	Bars, Shapes
AN-M 26	M	AM-3S	M-1	-	1.50	-	Bars, Shapes
AN-M-27	FS-1	AM-C52S	AZ-31x	3.0	0.20	1.0	Bars, Shapes
AN-M-29	FS-1	AM-C52S	AZ-31x	3.0	0.20	1.0	Sheets, Strips
AN-M-30	M	AM-3S	M-1	-	1.50	-	Sheets Strips
AN-M-30A	H	AM-265	AZ-63	6.0	0.15	3.0	Sand Castings
B	M	AM-403	M-1	-	1.50	-	Sand Castings
C	C	AM-260	AZ-92	9.0	0.10	2.0	Sand Castings
11348-A	G	AM-240	-	10.0	0.10	0.3	Permanent Mold Castings
11349-A	C	AM-260	-	9.0	0.10	2.0	Permanent Mold Castings
AN-T-71	J-1	AM-C57S	AZ-61x	6.5	0.15	1.0	Tubing
AN-T-72	FS-1	AM-C52S	AZ-31x	3.0	0.20	1.0	Tubing
AN-T-73	M	AM-403	M-1	-	1.50	-	Tubing

53450-2-2-T27

range from 70° to 212° Fahrenheit. In applications where magnesium is rigidly connected to other metals and is subject to appreciable variation in temperature, consideration must be given to this relatively high coefficient.

4-24. The dimensional stability of magnesium alloys in service is normally satisfactory. Some of the magnesium-aluminum alloys are subject to small amounts of permanent growth if exposed for long periods of time to temperatures exceeding 200° Fahrenheit. The growth depends upon the composition and condition of the alloy and upon the time and temperature of exposure. Growth tends to be greatest in the −T4 temper. It may be mostly eliminated by a stabilizing heat-treatment.

4-25. *Chemical properties.* Bare magnesium is resistant to attack by alkalis, chromic and hydrofluoric acids, and many organic chemicals including hydrocarbons, aldehydes, alcohols, phenols, amines, esters, and most oils. It is susceptible to attack by salts and galvanic corrosion from contact with dissimilar metals and other materials. Adequate protection of the metal against unfavorable conditions can be maintained generally by using proper surface finish and assembly protection.

4-26. *Mechanical properties.* A wide range of mechanical properties is specified for magnesium alloy products. These properties vary with the composition, condition (cast or wrought), details of fabrication, and heat-treatment. Mechanical properties frequently considered in aircraft design include values given in the tension test, in addition to shear strength, compressive yield strength, hardness, impact resistance, and fatigue strength.

4-27. *Temper.* Temper is the condition produced in the alloy by mechanically or thermally treating it to alter its mechanical properties. Mechanical includes cold-rolling, cold-working, etc; thermal includes annealing, solution and precipitation heat-treat, and stabilization treating.

4-28. *Temper designation system.* The hyphenated suffix symbol which follows an alloy designation denotes the conditon of temper (heat-treat or strain-hardening), to which the alloy has been processed. These symbols and their meaning are listed below:

–AC	As cast
–F	As fabricated
–O	Annealed
–W	Solution heat-treated—unstable condition
–T	Treated to produce stable tempers other than for –O
–T2	Annealed (cast products only)
–T3	Solution heat-treated and then cold-worked
–T4	Solution heat-treated
–T5	Artificially aged only
–T6	Solution heat-treated and then artificially aged
–T7	Solution heat-treated and stabilized
–T8	Solution heat-treated, cold-worked, and then artificially aged
–T9	Solution heat-treated, artificially aged and then cold-worked
–T10	Artificially aged and then cold-worked
–H1	Strain-hardened
–H2	Strain-hardened and partially annealed
–H3	Strain-hardened and stabilized

117

Added suffix digits 2, 4, 6, and 8 to the H1, H2, H3 symbols indicate the degree of strain hardening; i.e., 2 = ¼ hard, 4 = ½ hard, 6 = ¾ hard, and 8 = full hard.

4-29. **Alloys and Their Uses.** Comparison of the commercial magnesium alloys conforming to Air Force specifications is given in table 22. It includes chemical composition and general uses. In addition to the principal alloying elements given in this table, the following elements may be present in amounts not to exceed the percentages shown: Silicon 0.3 percent, copper 0.05 percent, nickel 0.01 percent, iron 0.005 percent. The DOW refers to the Dowmetal series of alloys produced by the Dow Chemical Company. MAZLO refers to the series of alloys produced by the American Magnesium Corporation. ASTM refers to the alloys specified by the American Society for Testing Materials.

4-30. Table 23 has been placed in this section to give you a convenient cross reference from the former designation of the specifications of magnesium alloys to the present Federal Specification System. Metals received from supply channels are marked with either the Air Force Specifications or the Federal Specifications.

4-31. Sheet, including plate and strip, is usually rolled hot, using extruded slabs as the rolling stock. Sheet is available in thicknesses from 0.016 to 0.219 inches; plate thicknesses from 0.250 to 1.000 inch. Strip has a maximum thickness of 0.125 inch and may be up to 8 inches wide. It is usually furnished in coils. Magnesium sheet can be arc-welded, gas-welded, and spot-

TABLE 23

ALLOY DESIGNATION CROSS-REFERENCE

NEW DESIGNATOR	FORMER DOW REVERE	FORMER AMERICAN MAGNESIUM	FORMER * MILITARY	NEW FEDERAL	USE
AZ63A	H	AM265	- - - -	QQ-M-56	Castings, Sand
MIA	M	AM3S	AN-M-26	QQ-M-31	Extruded Bars, Rods, Shapes
MIB	M	AM403	AN-M-30	QQ-M-56	Castings, Sand
MIA	M	AM3S	AN-T-73	WW-T-825	Extruded Tube
MIA	M	AM3S	AN-M-22	QQ-M-40	Forgings
MIA	M	AM3S	AN-M-30	QQ-M-44	Sheet
AZ92A	C	AM260	- - - -	QQ-M-56	Castings, Sand
AZ92A	C	AM260	- - - -	QQ-M-55	Castings, Perm Mold
AM100A	G	AM240	- - - -	QQ-M-55	Castings, Perm Mold
AZ91A	R	AM263	AN-M-16	QQ-M-38	Castings, Die
AZ31B	FS-1	AM52S	AN-M-27	QQ-M-31	Extruded Bar, Rod, Shape
AZ31B	FS-1	AM52S	AN-T-72	WW-T-825	Extruded Tube
AZ31B	FS-1	AM52S	- - - -	- - - -	Forgings
AZ31B	FS-1	AM52S	AN-M-29	QQ-M-44	Sheet
AZ61A	J-1	AMC57S	AN-M-24	QQ-M-31	Extruded Bar, Rod, Shape
AZ61A	J-1	AMC57S	AN-T-71	WW-T-825	Extruded Tubes
AZ61A	J-1	AMC57S	AN-M-20	QQ-M-40	Forgings
AZ80A	0-1	AMC58S	AN-M-25	QQ-M-31	Extruded Bar, Rod, Shape
AZ80A	0-1	AMC58S	AN-M-21	QQ-M-40	Forgings
ZK60A	--	AMA76S	- - - -	QQ-M-31	Extruded Bar, Rod, Shape
EK41A	--	AMA130	- - - -	- - - -	Castings, Perm Mold
EZ33A	--	AMA131	- - - -	- - - -	Castings, Perm Mold
TA54A	--	AM65S	- - - -	QQ-M-40	Forgings

NOTES: *These "AN" Specifications have been superseded by the listed Federal Specifications.

53450-2-2-T23

welded; formed; drawn; spun; and riveted. It has been used in such parts as aircraft wings, ailerons, fairings, oil and fuel tanks, ducts, floor plates, etc. Sheets can be furnished either annealed or hard-rolled. The following specifications of alloy sheet are commercially available.

4-32. AN-M-29 has the best combination of strength and toughness, but limited ability to be gas- or arc-welded. When annealed, it can be formed cold. When hard-rolled, it has excellent fatigue and shear strength.

4-33. AN-M-30 has moderate strength but the best adaptability to gas-welding. When annealed, it can be formed hot easily. When hard-rolled, it has the best resistance to creep at high temperatures.

4-34. **Working Characteristics.** The working characteristics of magnesium are similar to those of other metals. Magnesium may be worked by using the same methods and equipment as used on steel and aluminum, except that in most instances, magnesium can be worked easier in the elevated temperatures. Magnesium alloys are difficult to form at room temperature. Operations other than the most simple ones must be performed at higher temperatures. This requires preheating the metal or the dies or both.

4-35. Magnesium alloy sheets may be cut by blade shears, blanking dies, routers, or saws. Hand or circular saws are usually used for cutting extrusion to length. Conventional shears and nibblers are never used for cutting magnesium alloy sheet, because they produce a rough, cracked edge.

4-36. *Cutting*. Shearing and blanking require close tool tolerances. A maximum clearance of 3 to 5 percent of the sheet thickness is recommended. The top blade of the shears should be ground with an included angle of 45° to 60°. The shear angle on a punch should be 2° to 3°, with a 1° clearance angle on the die. For blanking, the shear angle should be the same as with the punch. The die should be 2° to 3°, with a 1° clearance angle on the punch. Cold-shearing must not be done on hard-rolled sheet thicker than 0.064 inch or annealed sheet thicker than 0.125 inch. Shaving is used to improve the characteristic rough, flaky edge of magnesium sheet which has been sheared. This operation consists of removing approximately 1/32 of an inch by a second shearing.

4-37. Hot-shearing is sometimes used to obtain an improved sheared edge. This is necessary for heavy sheet and plate stock. Annealed sheet may be heated to 600° Fahrenheit, but hard-rolled sheet must be held under 400° Fahrenheit, depending on the alloy used. Thermal expansion makes it necessary to allow for shrinkage after cooling, which entails adding a small amount to the cold metal dimensions before fabrication.

4-38. Sawing is the only method used in cutting plate stock more than ½ inch thick. Band saw raker-set blades of 4 to 6 tooth pitch are recommended for cutting plate stock or heavy extrusions. Small and medium extrusions are more easily cut on a circular cutoff saw having 6 teeth per inch. Sheet stock can be cut on band saws having raker-set or straight-set teeth with a pitch of 8 teeth per inch. Band saws should be equipped with nonsparking blade guides to eliminate the danger of sparks igniting the filings.

4-39. *Drilling*. The machining characteristics of magnesium alloys are excellent. Usually the maximum speeds of machine tools can be used with heavy cuts and high speed rates. Power requirements for magnesium alloys are about 1/6th of those for mild steel.

4-40. Three types of drills are used to obtain best results. For sheets, the recommended drill has a 60° point angle, 10° helix angle, and 120° to 135° chisel edge angle. For shallow holes, with a depth of less than five times the drill diameter, the drill will have a 70° to 118° point angle, 10° to 30° helix angle, 120° to 135° chisel edge angle, and 12° relief angle. For deep holes, the recommended drill has 118° point angle, 40° to 45° helix angle, and 135° to 150° chisel edge angle. A mineral base cutting oil facilitates drilling and is used when drilling deep holes. The maximum speeds obtainable on drilling equipment can be used for magnesium alloys, up to 2000 feet per minute.

4-41. *Riveting*. Riveting is the most commonly used method of joining magnesium alloys. Rivets are used in magnesium in much the same way as in aluminum, but with certain special changes in technique. Magnesium rivets are not used because they work-harden too rapidly. Several aluminum alloy rivets are available, but the 56S alloy, ¼ hard, is recommended because it has less galvanic corrosion effect. Steel, copper, brass, and other heavy metal rivets should not be used because of the danger of rapid corrosion.

4-42. The design of riveted joints governs size, type, and spacing. With 56S rivets, a diameter of approximately three times the sheet thickness is recommended. With sheets of unequal thickness, the rivet diameter should not be less than the thickness of the thickest sheet. Most of the common types of rivet heads can be used. Standard countersunk rivet heads can be used on machine countersunk parts. Rivets should not be closer to the edge of the sheet than twice their diameter, but two and one-half times is preferred (as with aluminum). A minimum of three times the rivet diameter is recommended for spacing between rivets in any direction; four times the diameter is preferred.

4-43. Riveting procedure is similar to that for other materials. Pneumatic hammers or squeeze riveters can be used, but squeeze riveters are preferred because they give more accurate control of driving pressure with minimum damage to the sheet. While rivet holes can be punched in thin sheet up to 0.040 inch thick, drilling is recommended for all thicknesses. Holes must be drilled in parts used in stressed structures. The clearance between rivet and hole must be as small as possible without interfering with insertion of the rivet.

4-44. *Grinding*. Rough grinding, although not widely used, can be done on magnesium to remove rough edges, or to shape a piece of magnesium alloy. A course grained, medium hard, open structure wheel should be used to avoid loading and to provide rapid cutting. Goggles must be worn while you are grinding. Magnesium grindings and dust are very flammable; consequently, dust-collecting equipment must be used. Magnesium should ordinarily be ground dry to facilitate dust collection.

4-45. *Fire hazards*. The grinding of magnesium, as well as some of the machining operations, will produce highly inflammable dust which, in the proper proportions with air, can ignite with explosive violence. Rough cuts usually produce chips of such size that they do not readily ignite. Fine cuts at high speeds, with dull or improperly designed tools, produce chips that may ignite. It is extremely important that the utmost precautions be taken to avoid a fire.

4-46. On heavy stock, a sufficient quantity of neutral mineral oil cutting fluids must be used. It is hazardous to use animal, vegetable, acid-containing oils, or any form of water emulsion as a coolant or lubricant, except a mixture of kerosene and lard oil.

4-47. Magnesium chips and dust must not be allowed to accumulate on the machines or clothing of the operators. Machines and adjacent floor areas must be kept clean. Dust from grinding operations should be immediately removed from the working area. Open flames and sparks must be kept away from finely divided magnesium at all times. Smoking is not allowed in the vicinity of magnesium machining operations.

4-48. Grinding equipment should be marked "For Magnesium Only." Iron, steel, or other metals must not be ground on equipment used for magnesium because of the danger of producing sparks. Sandpaper should be used for any polishing operations. The use of emery cloth is not recommended because of its tendency to cause sparking.

4-49. Grinding and filing of magnesium surfaces which have been chrome-pickled may cause sparks. You must observe special precautions to avoid accumulation of dust within the range of sparks. The accumulation of magnesium dust on benches, floors, window ledges, pipes, and the like must be avoided. Vacuum cleaners are not used to collect the magnesium dust. The dust should be swept up and placed in covered iron containers, and must not be mixed with the regular floor sweepings.

4-50. If you should have a fire while working with magnesium, it can be extinguished by carrying out the following instructions:

(1) An adequate supply of the recommended fire extinguishers should be placed near the machine being used. Recommended extinguishers are: G–1 powder; clean, dry, unrusted cast iron chips; graphite powder; clean, dry, sand; talc; or pitch.

(2) Extinguisher should be sprinkled over the fire in a layer approximately ½ inch deep. Additional material should be added to spots that smoke-excessively.

(3) Fires on combustible surfaces should be covered with extinguisher and the mass shoveled into an iron container.

WARNING: Water or any of the standard liquid or foam type extinguishers must not be used, as they will intensify the fire and may cause an explosion.

4-51. *Forming*. The methods and equipment used for forming magnesium are much the same types as commonly employed on other metals (i.e., drawing, pressing, stamping, and bending). Different tools and techniques are used because magnesium is best formed at elevated temperatures of 350° to 800° Fahrenheit. Magnesium alloys have poor cold formability, and work-harden rapidly at room temperature.

4-52. Formability is affected by alloy composition, temper, type of product (sheet or extrusion), and the kind of fabricating operations used. Most forming operations on sheet are done on hot stock with heated tools, especially those operations requiring deep draws or small radius.

4-53. Heating to the temperature required for hot-forming (sheet alloys) has almost no adverse effect on the properties of annealed sheet at room temperatures. Depending upon conditions, substantial strengthening of the alloy may result when it is formed. You should use annealed sheet where maximum formability is needed. Hard-rolled sheet can also be formed at elevated temperatures, but it cannot be heated to temperatures for maximum drawability without losing the hard-rolled properties. Hard-rolled sheet is used most often for applications requiring maximum strength and on which only a moderate amount of shaping is necessary, since the forming temperature must be limited to prevent excessive loss of mechanical properties.

4-54. Hot-working has some disadvantages. First, it is expensive and troublesome to heat dies and material. Secondly, there are problems in lubricating and handling materials at these temperatures. There are some advantages to hot-working magnesium in that it is more easily formed when hot than are other metals; and springback is reduced, resulting in greater dimensional accuracy.

4-55. When heating magnesium and its alloys you must watch the temperature carefully, as this metal is easily burned. Overheating also causes small molten pools to form within the metal. To prevent burning, magnesium must be protected with a sulfur dioxide atmosphere while being heated.

4-56. It is necessary that a suitable bend radius be provided for bending, drawing, or other shaping. As we mentioned, cold-working is very limited because magnesium will work-harden very rapidly. Some simple bending operations may be performed cold on sheet material, but the radius of bend must be at least 7 times the thickness of the sheet for annealed material and 12 times the thickness of the sheet for hard-rolled material, compared to a radius of 2 or 3 times the thickness of the sheet if the material is first heated for the forming operation.

4-57. Proper bending around a short radius requires the removal of sharp corners and burrs near the bend line. Layouts must be made with a soft pencil because any marring of the surface could result in fatigue cracking.

4-58. Press or leaf brakes can be used for making bends with short radii. Die and rubber methods should be used where bends are to be made at right angles, which complicate the use of a brake. Roll-forming may be accomplished cold on equipment used on aluminum.

4-59. **Corrosion Prevention.** Magnesium, because of its position in the electromotive series, is not regarded as a corrosion resistant metal. Its resistance to corrosion, like other metals, depends to a great extent, upon the purity of the metal, the environment to which it is exposed, and its contact with dissimilar metals.

4-60. Pure magnesium withstands corrosion better than any of its alloys. The degree of resistance to corrosion of the various alloys differs; i.e., the magnesium-lithium alloys show a greater susceptibility than do the magnesium-thorium combinations. Environments and susceptibility of magnesium, along with other metals and their protective finishes, will be covered in the next chapter. For the time being, let us consider the protective primers for magnesium.

4-61. Corrosion prevention of magnesium alloys, as with other readily corroded metals, requires protective primers if these metals are to provide satisfactory service. The particular primer for magnesium depends on the application of the metal. Air Force needs cover a wide range of extremely severe corrosive conditions, and therefore complete protection is necessary. But even the best of materials and procedures will not eliminate the problem of corrosion unless corrosion has been designed out of the aircraft structure. As an airframe repairman required to repair or replace many sections of the aircraft due to corrosion, you should keep in mind that if the technical order is not followed, you could defeat the original principles incorporated to prevent accumulation of moisture. For example, if there was a drain hole there originally, be sure you put the drain hole back in.

4-62. After you fabricate the repair parts and prior to installing them, consider the protective coating required, according to the type of metal being used, the type of metal being attached to and the type of fasteners. Three basic types of contacts are found in assembly. They should be treated in the following manner:

a. Magnesium to magnesium contact—gives all faying surfaces one or more coats of chromate pigmented primer.

b. Magnesium to dissimilar metals—use moisture impervious films to protect both magnesium and dissimilar metal; use dissimilar metals that are compatible with magnesium; separate metals so that any corroding medium cannot complete an electrical circuit; protect the magnesium.

c. Magnesium in contact with wood, paper, etc—seal these absorptive materials with paint, varnish, wax, latex, epoxy, or similar coatings; then treat the magnesium faying surface with chromate pigmented primer, as with magnesium to magnesium contact.

4-63. **Heat-Treating.** Of first importance in the heat processing of magnesium alloys is a clear understanding of the characteristics of the metal relative to heat. Pure magnesium will melt at approximately 1202° Fahrenheit. The melting points of the alloys range from 830° to 1204° Fahrenheit, according to their element constituency. During any heating of alloy items, specified temperature maximums must be closely adhered to, particularly during solution heat-treating. The metal is easily burned, and overheating will also cause formation of molten pools within it. Either condition results in ruin of the metal. Certain alloys such as AZ63A Type 1, or AZ92A Type 1, are subject to eutectic melting (melting of some of its elements) if heated too rapidly. They must be brought up to heat-treating temperature slowly enough to prevent this. In the case of these two examples, a minimum of 2 hours in required to bring them from 640° Fahrenheit to treating temperature.

4-64. An additional and no less important characteristic of magnesium relative to heat-treatment, is that it is subject to excessive oxidation at 750° Fahrenheit and higher temperatures. In an oxidizing atmosphere, this characteristic can result in ignition and fierce burning. To prevent such occurrences, a protective atmosphere containing sufficient sulfur dioxide, carbon dioxide or other satisfactory oxidation inhibitor must be used when heating to 750° Fahrenheit and over. When oxidation inhibitors are used, their concentration percentage in the furnace atmosphere should be periodically checked for correct amounts. The particular requirements for various alloys are detailed in TO 1-1A-9. These requirements and those of other pertinent specifications and instructions should be consulted and strictly adhered to in processing the metal. The safety measures defined in TO 1-1A-9 must be rigidly practiced.

4-65. *Heat-treating equipment.* Furnaces used for solution must be of the air chamber type with forced air circulation. Heating provisions can be gas, electricity, or oil. Their design must be such as to make impossible direct heating element radiation or flame impingement on the articles being treated. The furnaces must be installed with the necessary control, temperature measuring, and recording instrument equipment to assure complete and accurate control. The temperature control must be capable of maintaining a given temperature within 10° Fahrenheit at any point in the working zone after the charge has been brought up to this temperature. Each furnace must be equipped with a separate manual reset safety cutout which will turn off the heat source in the event of any malfunction or failure of the regular automatic controls. The safety cutouts must be set as close as practicable above

TABLE 24

SOLUTION HEAT-TREATING TEMPERATURES AND HOLDING TIME

ALLOY	TEMPERATURE RANGE	TIME PERIOD (HRS)	MAX TEMP°F
AM100A	790-800	16-24	810
AZ63A (Type 1)	720-730 (F to T4)	10-14	734
AZ63A (Type 2)*	720-740 (F to T4)	10-14	745
AZ81A	770-785	16-24	785
AZ91C	770-785	16-24	785
AZ92A (Type 1)	760-770	16-24	775
AZ92A (Type 2)	775-785	14-22	785
HK31A	1045-1055	2	1060
QE22A**	970-990	4-8	1000
ZK61A	925-935 or 895-905	2 10	935 935

*Contains calcium.

**Quench in 150°F water bath within 30 seconds after opening of furnace.

53450-2-2-T24

112

TABLE 25

ARTIFICIAL AGING (PRECIPITATION TREATMENT)

ALLOY & TEMPER	AGING TREATMENT
AM100A-T6	5 hrs at 450°F or 24 hrs at 400°F
AM100A-T5*	5 hrs at 450°F
AZ63A-T6	5 hrs at 425°F or 5 hrs at 450°F
AZ63A-T5*	4 hrs at 500°F or 5 hrs at 450°F
AZ91C-T6	16 hrs at 335°F or 4 hrs at 420°F
AZ92A-T6 (Type 1)	4 hrs at 500°F or 5 hrs at 425°F
AZ92A-T6 (Type 2)	5 hrs at 450°F or 16 hrs at 400°F or 20 hrs at 350°F
AZ92A-T5* (Type 2)	5 hrs at 450°F
EZ33A-T5*	2 hrs at 650°F + 5 hrs at 420°F or 5 hrs at 420°F
HK31A-T6	16 hrs at 400°F
HZ32A-T5*	16 hrs at 600°F
QE22A-T6	8 hrs at 400°F
ZH62A-T5*	2 hrs at 625°F + 16 hrs at 350°F
ZK51A-T5*	8 hrs at 424°F or 12 hrs at 350°F
ZK61A-T5*	48 hrs at 300°F
ZK61A-T6	48 hrs at 265°F

*T5 is aged from as-cast condition. Others are aged from T4 condition.

53450-2-2-T25

the maximum solution heat-treating temperature for the alloy being treated. This will be above the variation expected but should not be more than 10° Fahrenheit above the maximum heat-treat temperature of the alloy being processed. There must also be protective devices to shut off the heat source in case of circulation air stoppage. These devices must be interconnected with a manual reset control.

4-66. Upon initial furnace installation and after any maintenance on the furnace or its equipment which might affect its operational characteristics, a temperature survey must be made to test its capability of maintaining the minimum and maximum temperatures required for the various treatments it will be used for. A minimum of nine test locations within the furnace load area should be checked—one in each corner, one in the center, and one for each 25 cubic feet of furnace volume up to the maximum of 400 cubic feet. A monthly survey should be made after the initial survey, unless separate load thermocouples are employed, to record actual metal temperatures.

4-67. *Heat-treating solution.* Solution for heat-treating of magnesium alloyed articles is accomplished by heating at an elevated temperature in an air furnace for a specific time (holding period).

123

during which certain alloying elements enter into uniform solid solution. Since the alloys tend to become plastic at high temperatures, it is mandatory that suitable support be provided for articles being processed to prevent warping. Table 24 lists the recommended soaking and holding time for solution heat-treating alloys. The holding periods given are for castings up to 2 inches thick. Items thicker than 2 inches require longer periods.

4-68. *Precipitation heat-treatment.* Precipitation heat-treatment or artificial aging of alloys is accomplished at temperatures lower than those of the solution treatment. Suggested aging treatments for various alloys are shown in table 25.

4-69. *Stabilization heat-treatment.* Stabilization heat-treating an alloy increases its creep strength and retards growth at service encountered elevated temperatures. The same general procedures of heating to a temperature, holding for a time and cooling to room temperature, is used as in the other two types; only the temperature and time elements are different. When applied to a solution heat-treated alloy, it increases the alloy's yield strength. Stabilization treatment is a high-temperature aging treatment that is completed quickly rather than allowing an alloy to age naturally over a period of time.

4-70. *Annealing.* Magnesium alloys are annealed to relieve internal stresses resulting from forming operations, to soften the material for forming, to improve the ductility, or to refine the grain structure. The alloy is heated to the proper temperature, soaked or held at that temperature for a specified time and cooled to room temperature. The desired effects are gained by controlling the temperature, hold time, and cooling medium exposure. Avoid excessive time at the soaking temperature to prevent unwanted grain growth. Conversely, no attempt should be made to shorten the time at soaking temperature and overall annealing time by increasing the heating temperature, since elements of the alloys subject to melting points lower than the alloy itself can go into solution.

4-71. *Heat-treating procedures.* Placing of articles to be treated in the furnace (generally referred to as "charging the furnace") should not be done in haphazard fashion. Individual pieces should be racked or supported to prevent distorting without interfering with the free flow of the heated atmosphere around the article. Distortion or warping can occur due to the semiplastic qualities of the alloys at the furnace elevated temperatures during solution heat-treat. Distortion is not a particular problem during precipitation, stabilization, treatment, or annealing. However, it is good practice to handle magnesium alloy articles with care at all times under elevated heat conditions. In the case of complicated formed parts, it may be necessary to use a specially contoured jig or fixture to adequately protect the design contour of the item at high temperature.

4-72. Cooling after treating is accomplished in either still or blast air, depending on the alloy. The one exception is alloy QE 22A which is water quenched. The temperature of the water must be at 150° Fahrenheit.

4-73. **Requisitioning Magnesium.** Requisitioning or ordering of magnesium differs but slightly from aluminum, titanium, or steels, which we covered in the previous sections of this chapter. Magnesium sheet is to be found in the 9535 class. As with the other metals mentioned, the index of the C9500–IL–AF will identify the table for the particular metal. In this case magnesium sheet is found in table 324. Table 324 identifies it as: "Sheet, magesium alloy. Federal Specification QQ–M–44 possesses good physical properties and cold-forming characteristics. A weldable grade of magnesium alloy."

4-74. The material listed in table 324 of the –IL– contains sheet material in thicknesses from 0.016 to 0.190 inch thick, lengths of sheet from 96 inches to 144 inches long, and widths from 36 to 48 inches wide. The table further identifies the temper condition and the surface finish; i.e., chrome-pickled or unfinished.

4-75. After you have identified the particular piece of material that you desire, use the C9500–ML–AF to obtain the necessary data to obtain the material needed.

4-76. **Storage of Magnesium Sheet.** Storage of sheet magnesium is similar to the storage of aluminum and aluminum alloys, as previously discussed. Keep in mind two primary considerations, atmosphere and protection of the surface finish sheet.

4-77. All magnesium sheet must be stored in a dry, fully enclosed area and not exposed to weather and other corrosion-producing conditions. Storage must be away from windows and doors and not in the vicinity of heating systems containing steam or water pipes.

4-78. The metal surface must be protected from scratches, nicks, or other abrasions which could cause failure of the sheet after a part has been fabricated from it. This surface damage can be alleviated by interleaving magnesium with paper during storage. As with other metals, magnesium must not be stored in the vicinity of acids, caustics, nitrates, or phosphates.

4-79. **Inspection of Magnesium Repairs.** Inspection of repairs made with magnesium holds special significance to the airframe repairman because of the critical factors of cracking and brittleness of the material during fabrication. Previously we mentioned in fabrication that prior to forming operations, the edges of the material to be bent must be free of nicks or scratches to prevent cracking. In magnesium, even minute hairline cracks at the edges will cause failure of the material in a vibration area. Rivets must be of the 5056 type, which will still be identifiable after installation by the head marking of the rivet. Rivet spacing and edge distance are critical with magnesium alloys. Prior to approving a repair, you must insure that the material used in the repair is not of the dissimilar type that will create corrosion conditions, and insure that corrosion protective primers and finishes have been used during and upon completion of the repair.

5. Interchangeability

5-1. In selecting interchangeable or substitute materials for the repair and maintenance of aircraft, it is of the utmost importance to check the appropriate technical orders when specified materials are not in stock or obtainable from another source. It is impossible to determine that another material is as strong as the original by mere observation.

5-2. There are four requirements that must be kept clearly in mind in this selection. The first and most important of these is maintaining the original strength of the structure. The other three are: maintaining contour or aerodynamic smoothness; maintaining original weight, if possible, or keeping the added weight to a minimum; and maintaining the orginal corrosive-resistant properties of the metal.

5-3. The importance of checking the specific technical order will be appreciated if you understand that different manufacturers design structural members to meet various load requirements for specific aircraft. Structural repair of these members, apparently similar in construction, will thus vary in their load-carrying design with different aircraft.

5-4. Structural repair instructions (including tables of interchangeability and substitution for ferrous and nonferrous metals, and their specifications for all types of aircraft used by the Air Force) are normally prepared by the aircraft contractor. Such instructions are usually compiled in two separate series of handbooks and manuals. These are the 1-1A series of handbooks, known as *General Engineering Manuals*, and the -3 technical order of the basic handbook covering structural repair instructions for specific models of aircraft.

5-5. It is not our intention in this volume to cover all of the interchangeability or substitutions authorized for specific aircraft; you must use your appropriate -3 technical order for this. Instead, we cover the general requirements of substitution and substitution factors.

5-6. **Substitution Factors.** As we mentioned previously, strength, contour, weight, and corrosion resistance are of primary concern in selecting substitute material. We cannot select or substitute metals based on thickness, composition, or tensile strength factors only. However, there are some general rules that will make selection of metals easier to understand.

5-7. *Strength.* There are two basic rules which apply when substitution of material is necessary.

Rule 1: The substitute material shall provide cross-sectional strength in tension, compression, shear, and bearing at least equal to that of the original material.

Rule 2: Never substitute a material thinner than the original or with a cross-sectional area less than the original.

5-8. The explanation to rule 1 is that most parts in an aircraft structure carry a tension, compression, shear, and bearing load at some time during the operation of the aircraft. The magnitude of these loads is seldom known when repairs are made. Therefore, it is necessary that the tensile, compression, shear, and bearing strengths of a part made of a substitute material be at least equal to those of the original part. Strict adherence to rule 1 leads to the following paradox: If in one application 2024-T4 is substituted for 2024-T6 and if in another application 2024-T6 is substituted for 2024-T4, a substitute thicker than the original must be used in either application. This seeming inconsistency, which occurs with other combinations of metals, is explained by the following comparison of mechanical properties:

	2024-T4(bare)	2024-T6 (clad)
Ultimate tensile strength	62,000 pounds per square inch	60,000 pounds per square inch
Compressive yield strength	40,000 pounds per square inch	47,000 pounds per square inch

If 2024-T4 is substituted for 2024-T6, the substitute material must be thicker unless the reduction in compressive strength is known to be acceptable. On the other hand, if 2024-T6 is substituted for 2024-T4, the material must be thicker unless the reduction in tensile strength is known to be acceptable.

5-9. The explanation of rule 2 is that the buckling and torsional strengths of many sheet metal and tubular parts are dependent primarily upon the thickness rather than the allowable compressive and shear strengths of the material. Therefore, a substitute that is thinner than the original will reduce the buckling and torsional strengths of a part considerably even though the thinner substitute material has higher allowable compressive and shear strengths.

5-10. *Contour*. Maintaining the original contour of the original structure means that the flow of air over the completed repair will not create drag on the aircraft or change the flight characteristics due to a vortex or drag condition that you have created by your repair. It also means that the repair will include bends and angles incorporated in the original structure. During the substitution of metals, you must be extremely careful, especially during flush repairs, to insure that the material used can do the required job without creating new problems. If the strength cannot be maintained by using the original thickness of material, the strength is not to be increased at the sacrifice of smoothness, but in some instances, strength is maintained by increasing doubler or backing plate thickness.

5-11. *Weight*. Depending on the particular aircraft and the position of the repair on that particular aircraft, added weight can become a problem at times. Weight control is secondary in some cases, but it can become a primary problem. A control surface that requires balancing is an example of added weight being a major concern during repair. The weight of the substitute material should correspond to the original as closely as possible.

5-12. **Grouping of Metals and Alloys.** In the process of making repairs, compositions of similar metals and alloys must be continually kept in mind when making substitutions in materials to fabricate a repair. Galvanic corrosion occurs when dissimilar metals are in contact and an external electrolytic circuit is created which results in a buildup of corrosion at the joint between the metals. For example, aluminum and magnesium skins riveted together in an aircraft wing form a galvanic couple if moisture and contaminations are present. When aluminum pieces are attached with steel bolts or screws, galvanic corrosion can occur between the aluminum and the steel.

5-13. Metals grouped together in table 26 have no strong tendency to produce galvanic corrosion each with the other, and are relatively safe to use in contact with each other. The coupling of metals from different groups shown in the table usually results in galvanic or accelerated corrosion of the metal higher on the list. The farther apart the grouping of metals is in the table, the greater will be the galvanic tendency, as can be determined by measurement of the electrical potential difference between them. It follows, then, that metals in Group I will have more galvanic tendency with metals in Group IV than with metals in Groups II or III.

5-14. All other commonly used metals will cause corrosion of magnesium in strong salt environment. Cadmium or zinc plating on the more cathodic metals such as iron and steel will greatly reduce galvanic corrosion. Tin-plated metal, when connected to magnesium, causes less corrosion than cadmium or zinc plated metal. This is because, in this unusual circumstance, the tin polarizes and then acts as an insulator. This is a contradiction; hence, it must be kept in mind that the galvanic series of metals and alloys are to be used for general information and that exceptions do exist.

5-15. The use of aluminum alloys containing magnesium, such as 5052 and 5053, usually will satisfactorily reduce galvanic corrosion of the magnesium alloys and also reduce simultaneous corrosion of the aluminum. Under severe exposure, when the contact of magnesium alloys and plated steel bolts is necessary, the use of 5052 aluminum washers may prevent severe galvanic attack.

5-16. Continuity of the liquid path may also be broken by the use of vinyl or polyester tapes. When conditions favorable to galvanic corrosion are unavoidable, always protect both portions of a couple.

5-17. When practical, rivets, bolts, and other fasteners should be made of the same material as the main structure. When not practical, they should be selected from materials lower in table 13, in order to distribute the anodic attack over the larger surface area of the two coupled metals. This is particularly important where the fasteners are subjected to high stress and where the safety factor is low. However, the structural strength

TABLE 26

GROUPING OF METALS AND ALLOYS

Group I	Magnesium and its alloys; aluminum alloys 5052, 5056, 5356, 6061, and 6063.
Group II	Cadmium, zinc, and aluminum and their alloys (including the aluminum alloys in Group I).
Group III	Iron, lead, and tin and their alloys (except stainless steel).
Group IV	Copper, chromium, nickel, silver, gold, platinum, titanium, cobalt, and rhodium and their alloys; stainless steel and graphite.

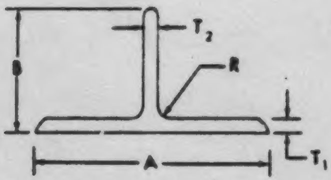
Metals classified in the same group are considered similar to one another.

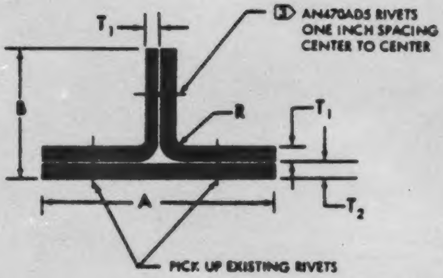
Metals classified in different groups are considered dissimilar to one another.

53450-2-2-T26

116

TABLE 27
SUBSTITUTE REPAIR MATERIAL





Notes

1. ALL DIMENSIONS ARE IN INCHES.
2. AFTER FORMING, HEAT TREAT O MATERIAL TO T CONDITION PER SPECIFICATION MIL-H-6088.

3 USE AN470DD6 RIVETS WHEN THICKNESS (T) IS .080 OR LARGER.

EXTRUDED TEES (SYMMETRICAL)

EXTRUSION NUMBER	DIE NUMBER	MAT'L: AL. AL.	A	B	T_1	T_2	R
AND10136-1601		2024-T4 7075-T6	1.750	.875	.094	.094	.125
AND10136-1605		2024-T4	1.750	1.375	.094	.094	.125
AND10136-1706		2024-T4	1.875	1.500	.094	.094	.125
AND10136-2001		7075-T6	2.000	1.000	.078	.078	.125
AND10136-2002		7075-T6	2.000	1.000	.094	.094	.125
AND10136-2004		7075-T6	2.000	1.250	.078	.078	.125
AND10136-2005		7075-T6	2.000	1.250	.094	.094	.125
AND10136-2006		7075-T6	2.000	1.250	.125	.125	.125
AND10136-2007		7075-T6	2.000	1.750	.094	.094	.125
AND10136-2401		7075-T6	2.500	1.250	.094	.094	.125
AND10136-2402		7075-T6	2.500	1.250	.125	.125	.125
AND10136-2404		7075-T6	2.500	1.625	.094	.094	.125
AND10136-2405		7075-T6	2.500	1.625	.125	.125	.125
AND10136-2406		7075-T6	2.500	1.625	.156	.156	.125
AND10136-2408		2024-T4	2.500	2.000	.156	.156	.125
AND10136-3001		7075-T6	3.000	1.500	.125	.125	.125
AND10136-3004		7075-T6	3.000	2.000	.188	.188	.188
AND10136-3005		2024-T4	3.000	2.500	.125	.125	.125
NAS344-43		2024-T4	1.750	1.125	.078	.078	.125
NAS344-44		7075-T6	1.750	1.375	.078	.078	.125
NAS344-69		7075-T6	3.000	1.500	.188	.188	.125
NAS344-78		7075-T6	3.500	2.875	.250	.250	.188
1M517	ALC15281	2024-T4	2.500	1.500	.070	.093	.125
1M549	ALC23320	2024-T4	3.500	.875	.064	.064	.094
1M558	ALC22899	7075-T6	1.875	1.000	.050	.050	.090
1M568	ALC12482	7075-T6	2.500	2.437	.094	.094	.187
1M2141	ALC61862	2024-T4	2.000	2.440	.094	.094	.125
1M5109	ALC57361	2024-T4	1.750	2.330	.100	.170	.094
1M5115	ALC57369	7075-T6	2.000	2.900	.100	.160	.125
1M5139	HAR15657	2024-T4	2.100	2.500	.170	.090	.125
1M5156	ALC57973	7075-T6	2.240	1.340	.081	.081	.125
1M5164	ALC61128	2024-T4 7075-T6	2.120	2.120	.063	.063	.125
1M5165	ALC61127	7075-T6	2.380	1.250	.063	.063	.125
1M5184	ALC61384	7075-T6	3.500	3.250	.100	.160	.125
1M5193	ALC66017	7075-T6	4.000	1.500	.094	.094	.125
1M5194	ALC55956	7075-T6	2.800	2.200	.078	.078	.130
1M5218	ALC61798	7075-T6	3.500	1.250	.063	.063	.125
1M5229	HAR16982	7075-T6	3.120	1.000	.072	.072	.094
1M5255	HAR17129	7075-T6	3.800	.675	.125	.125	.125
1M5261	ALC26847	7075-T6	2.360	2.250	.095	.064	.130
1M5272	ALC66030	7075-T6	3.850	2.125	.094	.094	.125
1M5276	HAR17267	7075-T6	1.900	1.980	.094	.100	.125
1M5278	HAR17262	7075-T6	2.820	.730	.125	.066	.125
1M5345	REY9769	7075-T6	3.400	1.430	.150	.125	.125
1M5433	REY11297	7075-T6	3.900	.675	.180	.125	.125
1M5436	REY11298	7075-T6	2.560	1.155	.175	.125	.125
1M5441	HAR5441	7075-T6	2.060	.900	.063	.063	.125
1M5476	HAR21908	7075-T6	5.800	.750	.156	.080	.120

SHEET METAL EQUIVALENTS

EXTRUSION NUMBER	MAT'L: ALCLAD	A	B	T_1	T_2	R
AND10136-1601	2024-O 7075-O	1.750	.875	.071	.071	.13
AND10136-1605	2024-O	1.750	1.375	.071	.071	.13
AND10136-1706	2024-O	1.875	1.500	.071	.071	.13
AND10136-2001	7075-O	2.000	1.000	.063	.063	.13
AND10136-2002	7075-O	2.000	1.000	.071	.071	.16
AND10136-2004	2024-O	2.000	1.250	.063	.063	.13
AND10136-2005	7075-O	2.000	1.250	.071	.071	.16
AND10136-2006	7075-O	2.000	1.750	.100	.100	.22
AND10136-2007	7075-O	2.000	1.750	.071	.071	.16
AND10136-2401	7075-O	2.500	1.250	.071	.071	.16
AND10136-2402	7075-O	2.500	1.250	.100	.100	.22
AND10136-2404	7075-O	2.500	1.625	.071	.071	.16
AND10136-2405	7075-O	2.500	1.625	.100	.100	.22
AND10136-2406	7075-O	2.500	1.625	.125	.125	.28
AND10136-2408	2024-O	2.500	2.000	.125	.125	.19
AND10136-3001	7075-O	3.000	1.500	.100	.100	.22
AND10136-3004	7075-O	3.000	2.000	.160	.160	.38
AND10136-3005	2024-O	3.000	2.500	.100	.100	.16
NAS344-43	2024-O	1.750	1.125	.063	.063	.13
NAS344-44	7075-O	1.750	1.375	.063	.063	.13
NAS344-69	7075-O	3.000	1.500	.160	.160	.38
NAS344-78	7075-O	3.500	2.875	.190	.190	.44
1M517	2024-O	2.500	1.500	.071	.050	.13
1M549	2024-O	3.500	.875	.050	.050	.09
1M558	7075-O	1.875	1.000	.040	.040	.09
1M568	7075-O	2.500	2.437	.071	.071	.16
1M2141	2024-O	2.000	2.440	.071	.071	.13
1M5109	2024-O	1.750	2.320	.125	.071	.19
1M5115	7075-O	2.000	2.900	.125	.071	.28
1M5139	2024-O	2.100	2.500	.071	.190	.13
1M5156	7075-O	2.240	1.340	.063	.063	.13
1M5164	2024-O 7075-O	2.120	2.120	.050	.050	.13
1M5165	7075-O	2.380	1.250	.050	.050	.13
1M5184	7075-O	3.500	3.250	.125	.071	.28
1M5193	7075-O	4.000	1.500	.071	.071	.16
1M5194	7075-O	2.800	2.200	.063	.063	.13
1M5218	7075-O	3.000	1.250	.050	.050	.13
1M5229	7075-O	3.120	1.000	.063	.063	.13
1M5255	7075-O	3.800	.675	.100	.100	.22
1M5261	7075-O	2.360	2.250	.050	.090	.13
1M5272	7075-O	2.850	2.125	.071	.071	.16
1M5276	7075-O	1.900	1.980	.080	.071	.19
1M5278	7075-O	2.820	.730	.063	.125	.13
1M5345	7075-O	3.400	1.430	.100	.125	.28
1M5433	7075-O	2.900	.675	.100	.190	.44
1M5436	7075-O	2.560	1.155	.100	.190	.44
1M5441	7075-O	2.060	.900	.050	.050	.13
1M5476	7075-O	5.800	.750	.080	.160	.38

53450-2-2-T27

127

TABLE 28

ALUMINUM ALLOY SUBSTITUTION AND CONVERSION TABLE FOR COMMERCIAL TEMPER DESIGNATIONS

Material to be Replaced	New Or Substitute Material															
	7075 -T6	Clad 7075 -T6	Clad 2024 -T86	Clad 2024 -T84	Clad 2024 -T81	2024 -T36	Clad 2024 -T36	Clad 2024 -T6	2024 -T4	Clad 2024 -T4	6061 -T6	Clad 2014 -T6	Clad 2014 -T4	5052 -H38	5052 -H36	5052 -H34
7075-T6		1.08	1.07	1.08	1.22	1.37	1.46	1.43	1.68	1.81	1.92	2.04	2.10	2.10	2.40	2.92
Clad 7075-T6	1.00		1.00	1.00	1.13	1.27	1.35	1.32	1.55	1.68	1.77	1.88	1.94	1.94	2.22	2.70
Clad 2024-T86	1.00	1.00		1.02	1.15	1.29	1.37	1.34	1.58	1.71	1.80	1.91	1.96	1.96	2.26	2.74
Clad 2024-T84	1.00	1.00	1.00		1.13	1.27	1.35	1.32	1.55	1.68	1.77	1.88	1.94	1.94	2.22	2.70
Clad 2024-T81	1.00	1.00	1.00	1.00		1.13	1.20	1.17	1.38	1.49	1.57	1.67	1.72	1.72	1.97	2.40
2024-T36	1.00	1.00	1.00	1.00	1.00		1.07	1.05	1.18	1.33	1.40	1.49	1.53	1.53	1.75	2.14
Clad 2024-T36	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.15	1.25	1.32	1.40	1.44	1.44	1.65	2.00
Clad 2024-T6	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.18	1.27	1.35	1.43	1.47	1.47	1.68	2.05
2024-T4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.08	1.15	1.22	1.25	1.25	1.43	1.74
Clad 2024-T4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.06	1.12	1.16	1.16	1.32	1.61
6061-T6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.06	1.10	1.10	1.15	1.53
R301, Clad 2014 -T6	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.03	1.03	1.18	1.44
R301, Clad 2014 -T4	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.15	1.39
5052-H38	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.15	1.39
5052-H36	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.22
5052-H34	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

53450-2-2-T28

of the aircraft must not be endangered by substituting incorrect parts. Refer to the specific technical orders involved or to the prime support systems manager for repairs not specifically authorized. In the following chapter, we will discuss the corrosive potential if such a repair should be made which will create corrosive potential.

5-18. **Extrusion Substitution.** We have previously discussed extrusion, how it is formed, and its composition. In the repair process of maintaining aircraft, there will be occasions when the damage will include the extruded shapes used in the structure of the aircraft.

5-19. In the event of damaged extrusion, it will be up to you to determine the proper replacement of the piece and if not available to identify the dimensions and forming angles of authorized substitutions that can be formed from sheet stock. Table 27 shows a typical extracted page of a technical order that you would use to determine the substitute material, metal thickness, and proper forming angles. For example: If the repair figure in the –3 technical order identifies the extrusion to be numbered AND10136–2404, the material to be used in the repair would be identified in the extrusion table as 7075–T6 aluminum alloy with a base (marked A) 2.500 inches wide and a leg (marked B) 1.625 inches wide. The thickness of the base (marked T1) is .094 inch and the leg is also .094 inch thick. All radii on the extrusion (marked R) are ⅛ inch or 0.125. If the extrusion of the same composition and dimensions can be obtained, it is used to make the necessary repair in compliance with the –3 technical order.

5-20. Many occasions will arise when such extrusion is not available and must be fabricated from flat sheet stock. Using the equivalent side of table 27, you would need to find the extrusion number for substitute dimensions. In this example this is AND10136–2404. The material to be formed would be 7075–0, aluminum alloy (7075 in the annealed condition). The base and leg material would be the same. The dimensions of the base and leg would also remain the same as the original with a base 2.500 inches wide and a leg of 1.625. (Note that in the repair sample, three pieces are needed to replace the extruded original.) In the replacement part, T1 would include the T1 and T2 of the original part. T1 would be made 0.071 inches thick and T2 would be 0.071 includes thick. The radius of the angles would go from 0.125 on the original extrusion to 0.160 inch on the substitute material to allow for the bending of the sheet stock with a bending brake.

5-21. After the substitute pieces have been formed and dressed, heat-treating is necessary to give the material the strength needed to carry the stresses involved. Note at the top of table 27 that the material should be heat-treated to the –T condition. In this particular case, it must be brought to the –T6 condition, the same as the original extrusion.

5-22. **Thickness Substitution.** Previously we discussed the necessity for maintaining the original strength of substitute materials. Table 28 is an extract from TO 1–1A–9, showing the solution of substitution between aluminum alloy sheet stock.

5-23. The following guidelines apply to the use of table 28:

a. Locate the horizontal row containing the symbol of the material to be replaced.

b. Locate the vertical column containing the symbol of the substitute material.

c. To obtain the thickness of the substitute material, multiply the thickness of the material to be replaced by the factor at the intersection of the row and column found by the first and second steps respectively. For example, to find the thickness of clad 2024–T6 that is to replace clad 7075–T6 of 0.032-inch thickness:

- Clad 7075–T6 is in the second horizontal row of factors.
- The substitute clad 2024–T6 is in the eighth vertical column of factors.
- The required factor is 1.32; 1.32 × 0.032 is equal to 0.042 inches. The minimum thickness of the substitute clad 2024–T6 is 0.042-inch material.

5-24. Before we continue to Chapter 2, turn to the workbook and answer exercises for Sections 4 and 5.

Corrosion Control of Metals

PROGRESS IN THE manufacture of aircraft metals and advanced techniques of repair and corrosion prevention are keeping pace with advanced research to reduce or prevent corrosion and to increase the useful life of the metals we now have. Corrosion and deterioration of metal have taken place since the discovery of metals. However, corrosion was not recognized as a serious problem until the development of modern technology. To give you an idea of the seriousness of the situation, it has been estimated that the monetary losses sustained by the military services as the result of corrosion amount to several billions dollars a year.

2. In the previous chapter you studied the characteristics of particular metals to resist corrosion. In this chapter you will study how corrosion potential is created and recognized, the different types of corrosion and their causes, and other factors that effect corrosion so you can detect, correct, and prevent corrosion in your everyday work assignments.

6. Corrosion Recognition

6-1. The corrosive destruction or attack on metals involves chemical and physical processes which are evidenced by tarnish, general attack, pitting, perforation, or cracking of the metal. The attack varies with the metal and with the physical environment and conditions to which the metal is subjected.

6-2. Corrosion recognition and treatment (control) are of major importance to all aircraft maintenance personnel and the airframe repairman in particular. They are vital because corrosion of equipment and primary stucture have a great effect on the capability, and on the operational and structural integrity of any weapon system. Corrosion potential and the control of the corroded area pose another challenge for you to recognize and prevent further deterioration of the systems you repair.

6-3. Because corrosion can ultimately weaken primary structural members sufficiently to require replacement or reinforcement in order to sustain designed loads, scheduled inspections and preventive maintenance are essential to early detection and correction of corrosion or its potential. If while you are on a job you can identify corrosion effects within the area, correction at that time lessens the total amount of labor that would be needed to correct the situation at a later date, and insures that corrosion will not damage a weapon system.

6-4. Before we get into the effects and identification of the specific types of corrosion, a review of the definition and causes of corrosion is in order.

6-5. **Corrosion Defined.** Corrosion is defined as the deterioration of a metal by a chemical or electrochemical reaction with its environment. Essentially, all reactions of metals in gaseous atmosphere (oxygen and water-vapor) or in electrical conducting liquids or electrolytes (commonly aqueous solutions of salts, acids, or bases) are electrochemical in nature. High temperature gaseous corrosion of metals is not generally considered as electrochemical. The reaction involves the direct union of gas atoms or molecules with the metal (ions) to form oxidation products (oxide in the case of oxygen or chloride in the case of chlorine).

6-6. **Factors in Corrosion Control.** The degree of severity, rate of corrosion, and the causes and types of corrosion depend on many factors. Certain factors cannot be controlled in the field at squadron level and must be accepted. However, when properly controlled, preventive maintenance will materially reduce the possibility and degree of corrosion. Most of the factors are divided into five groups:

- Effect of section size.
- Effect of material selection.
- Effect of geographical location and environment.
- Effect of heat treatment.
- Effect of preventive maintenance.

120

6-7. *Effect of section size.* Thick structural sections are subject to corrosive attack because of possible variations in their composition, particularly if the sections are heat-treated during fabrication. Similarly, when large sections are machined or chem-milled after heat-treatment, the physical characteristics of thinner sections will be different from those of thicker areas. Section size is based on structural requirements and cannot be changed for the purpose of controlling corrosion. From a maintenance standpoint, the correct approach is one of recognizing the critical nature of the integrity and strength of major structural parts and of maintaining permanent protection over such areas at all times in order to prevent deterioration. When two dissimilar metals are used and possible contact may develop, remember that if the surface of the more active member of the pair is small compared with the surface of the less active member, attack will be severe and extensive when insulation breaks down. If the cathode or less active member is small compared to the anode, anodic attack will be superficial or general. For example, an aluminum fastener in contact with a relatively inert titanium structure may corrode severely, while a titanium bracket secured to a large aluminum member would result in relatively superficial attack of the aluminum sheet.

6-8. *Effect of material selection.* One of the fundamental factors in corrosion is the nature of the material. High strength, heat-treatable aluminum and magnesium alloys are very susceptible to corrosion while titanium and stainless steels are less susceptible in atmosphere environment. Materials must be selected primarily for structural efficiency, however, and corrosion resistance is necessarily a secondary consideration in design. The use of more corrosion-resistant materials in any design normally involves additional weight to achieve the strength. Since weight considerations are a major factor in constructing airframes, particularly in missiles, the primary means of preventing corrosion is by proper maintenance procedures. The use of corrosion-resistant alloys is not a cure-all for corrosion prevention. Corrosion-resistant metals are by nature passive and can cause severe galvanic corrosion of less noble neighboring materials. A common mistake is to replace a corroded part with a corrosion-resistant alloy only to find that the corrosion has shifted and increased in severity.

6-9. *Effect of geographical location and environment.* This factor concerns weapon systems exposed to marine atmosphere, moisture, tropical temperature conditions, industrial chemicals, soils, and dust in the atmosphere. This factor naturally is controlled by the requirement for establishing operating bases at specific geographical locations.

6-10. *Effect of heat-treatment.* Proper heat-treatment of metals is a vital factor in establishing its resistance to corrosion. Heat-treatment is used to interlock the molecules or grains of the internal metallic materials in such a way as to resist intermolecular action. Improper heat-treatment results in undesired hardness and makes the material subject to intergranular chemical reaction.

6-11. *Effect of preventive maintenance.* The most vital factor is preventing corrosion, and the one which can be controlled only by field personnel, is the removal of the electrolyte. The term "electrolyte" refers here to contaminating materials (moisture, salt, dirt, grease, fluids, etc.) which come in contact with the metal surfaces. The corrosive effect is determined by the composition of the contamination, the type of metal, and the length of time the materials remain in contact. As explained previously, the extent of attack is almost always inversely proportional to the frequency of cleaning. Thus, the more frequently a surface is cleaned the less the possibility of corrosive attack. Anodic and chemical treatments as well as proper paint finishes should be applied in the critical areas to protect aluminum and magnesium alloys. The purpose of these coatings is to provide a barrier to inhibit the action of corrosive environment.

6-12. **Causes of Corrosion.** Corrosion may proceed at a rapid or slow rate. The rate depends on the metal undergoing attack, the environment, the concentration of reactants, and the prevailing temperature. Inasmuch as the metal may vary from high purity to an alloy containing various other elements, a wide variety of corrosion behavior is possible. Physical structure variability, because of heat-treatment, quenching, or cold-working, also will influence the susceptibility to corrosion. The shape, form, or finish of the metal concave shapes, sumps for the accumulation of corrodants, cast or wrought forms, and grit blasted, or mechanical finishes) will influence the rate of reaction between the metal and the corrosive agents. Control of environmental conditions, such as moisture content, chemical contaminants, and temperature, can accentuate or moderate corrosive reactions to a significant degree.

6-13. Environmental conditions greatly influence the nature and extent of damage to metals. The form of attack could be of a general type or it might be of a localized or specific nature. The many variables and factors which are involved in the corrosive environment should be analyzed and understood as fully as possible

132

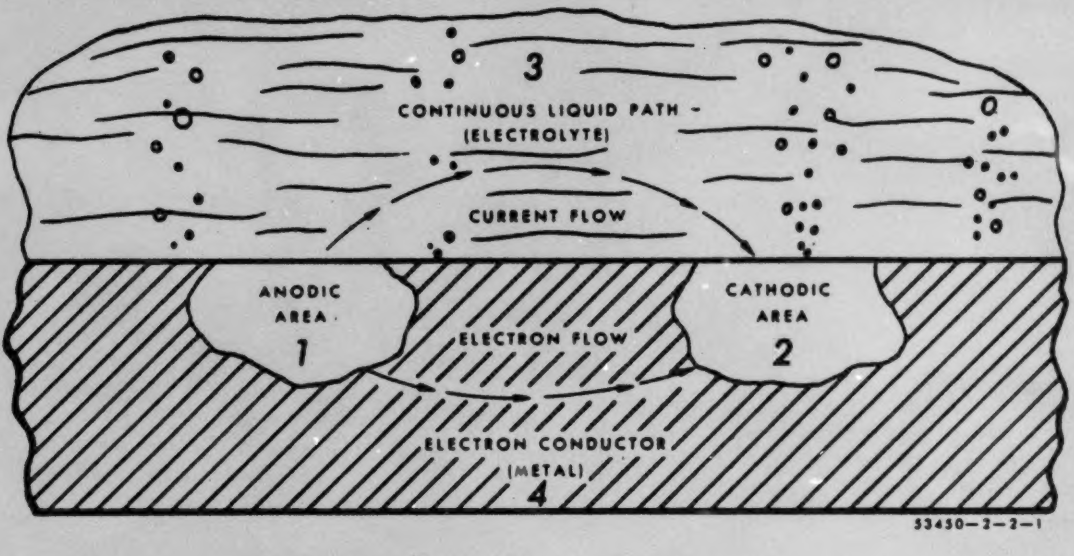


Figure 10. Conditions for electrochemical corrosion.

so that workable and dependable measures can be devised to counter the corrosive process.

6-14. *Corrosion conditions.* Corrosion occurs because of the tendency of most metals to return to their natural state. (Iron in the presence of moist air will revert to its natural state, iron oxide, rust.) Metals are also corroded by the direct action of the metal to a chemical. To enable you to better understand the causes and results of the various types of corrosion, let's consider what happens in electrochemical reaction (corrosion). Four conditions must exist before electrochemical corrosion can occur. (See fig. 10.) Under these conditions there must be something that corrodes the metal (metal anode); there must be a cause (cathode); there must be a continuous liquid path (electrolyte, usually condensate and salt or other contaminations); and there must be a conductor to carry the flow of electrons from the anode to the cathode. This conductor is usually in a form that provides for metal-to-metal contact (rivets, bolts, welds, etc.).

6-15. The elimination of any one of the four conditions will automatically stop corrosion. For example, an organic film applied to the surface of the metal will prevent the electrolyte from connecting the cathode and the anode and the current cannot flow; therefore, no corrosion will occur.

6-16. At normal atmosphere temperatures, metals do not corrode appreciably without moisture, but moisture in the air is usually enough to start action. Oxygen is also usually essential for serious corrosion to take place in ordinary water at room temperature. Other factors that cause a metal to corrode are: acidity or alkalinity of the conductive medium (pH factor); stability of the corrosion products; biological organisms, particularly anaerobic bacteria; variation in composition of the corrosive medium; temperature; etc.

6-17. The initial rate of corrosion is usually much greater than the rate after a short time, because the oxide film which forms on a metal surface tends to protect the metal underneath. This is not true of stress corrosion.

6-18. *Effects of environment.* When a metal is exposed to an environment, there are certain characteristics of the environment that influence the progress of corrosion. We need to discuss some of the more important ones.

6-19. Acidic environments are generally quite corrosive to metals more active than hydrogen because of the tendency for the metal ions to displace hydrogen, resulting in the continued dissolution of metal. Metals such as aluminum or zinc may corrode in alkaline solution because soluble salts are formed at anodic areas, and there is little tendency for polarization to occur, resulting in continued corrosion of the metal.

6-20. In some corrosion processes, such as in acid solutions, hydrogen is generally evolved as a gas. Metals are not often used in environments which would produce excessive hydrogen gas evolution. Frequently the corrosion which occurs in typical service environments is mitigated by a thin film of hydrogen gas which forms on the surface of cathodic areas (this is known as hydrogen polarization), which in effect lessens the flow of current in the system, hence lowering the corrosion rate. If a hydrogen depolarizer is introduced (usually dissolved oxygen from the air). the hydrogen film can be destroyed or removed and the corrosion will proceed at the original rate. It is also possible for direct cathodic reduction of oxygen into water by electrons to form hydroxyl ions. giving the same results.

6-21. If a mildly acidic solution is saturated with dissolved oxygen. the rate of corrosive attack on common metals that do not develop protective film may be multiplied as much as 100 times. as compared with conditions where oxygen is not present.

6-22. While oxidizing agents may markedly accelerate corrosion of some metals. they may retard the attack on other metals by hastening the development of protective films of oxides of absorbed oxygen. Aluminum. chromium. and titanium are protected in this manner by oxidizing agents. By combining sufficient quantities of these metals with other metals. the resulting alloys frequently will possess improved corrosion resistance.

6-23. Corrosion is generally accelerated by rising temperature. An increase in temperature results in increased conductivity of the electrolyte. and increased solubility and diffusion rate of normally protective corrosion products. Cathodic depolarization by dissolved oxygen is increased by an increase in temperature because of more rapid diffusion of oxygen. On the other hand. at over 176° Fahrenheit. the solubility of oxygen in solution becomes very small and the corrosion rate is decreased.

6-24. *Effects of metal composition.* Some of the more important characteristics of a metal that influence the progress of corrosion must be discussed. Generally, most metals and alloys must be properly heat-treated to derive the maximum corrosion resistance benefits from alloying. For example. the steels containing carbon (martensitic) are usually quenched and tempered to provide the desired corrosion-resistant properties; and the stainless (austenitic) steels are more resistant in the annealed condition and must be properly treated to resist intergranular corrosion. If some aluminum alloys are quenched slowly. their corrosion resistance is decreased. These alloys become especially vulnerable to intergranular attack and must be artificially aged after slow quenching.

6-25. The different structures (nonhomogeneity) in an alloy may promote corrosion under some conditions. When the degree of difference is such that localized areas possess electrical potentials different from the remainder of the material. anode and cathode areas will exist.

6-26. When two dissimilar metals are immersed in an electrolyte and contacted electrically. a current will flow. The more active metal (anode) of the couple begins to corrode and the less active metal (cathode) is protected. The limitations of the electromotive series which make it unsuited for practical use with many metals have been indicated. Another relation has been developed that takes into consideration overall and practical aspects as well as theoretical principles. and is referred to as the Galvanic Series (shown in table 29). in which sea water is used as the electrolyte. The metals grouped together can be joined with a minimum of galvanic corrosion; the coupling of metals from adjacent groups will exhibit a slightly greater galvanic effect; metals distantly located in the list will result in appreciable or intense galvanic action.

6-27. **Visual Inspection.** Without proper and systematically performed inspections and maintenance. corrosion may seriously damage any weapon system. All equipment must be carefully inspected at each scheduled inspection for signs of corrosion. Under extreme conditions of humidity. temperature. and atmospheric conditions due to geographical location. the frequency of corrosion inspections may vary. Materials that require special treatment to safeguard them against corrosion are those most subject to corrosive attack and will require more careful inspection and maintenance.

6-28. *Typical locations.* The first appearance of corrosion on unpainted aluminum surfaces is in the form of deposits or spots. especially around skin seams. lap joints. areas where sand or dirt and grime collect. or in niches and crevices where traces of cleaning compound have accumulated. Particular attention should be directed toward areas where moisture does not evaporate as rapidly as in other locations more directly exposed to sun and air. Areas subjected to battery acids. relief tube spray. smoke. exhaust fumes. and gunfire gases require closer attention and more frequent maintenance.

6-29. Corrosion will be less on painted. aluminum coated. or aluminum plated surfaces than on unprotected surfaces: however. corrosion will attack protected metals if moisture permeates the protective coating to the metal surface. If so. the affected areas generally have a scaly or blistered appearance. or sometimes a paint discoloration. Corrosion on aluminum. magnesium. and plated steel surfaces can often be recognized if the area is dulled or pitted. and sometimes by whitish. greyish. or reddish powdery deposits.

6-30. *Interior surfaces and lap joints.* When you inspect interior surfaces and lap joints. give particular attention to areas where drain holes may become clogged. to fittings and braces. to compound parts inside the aircraft. to sections

TABLE 29
GALVANIC SERIES OF METALS AND ALLOYS

Anodic End	**Magnesium**
	Magnesium Alloys
	Zinc
	Alclad
	Aluminum 6053
	Cadmium
	Aluminum 2024
	Cast Iron
	Wrought Iron
	Mild Steel
	13% Chromium Steel Type 410 (Active)
	18-8-3 Chromium Nickel Stainless Steel Type 316 (Active)
	18-8 Chromium Nickel Stainless Steel Type 304 (Active)
	Tin
	Lead
	Lead Tin Solders
	Naval Brass
	Manganese Bronze
	Muntz Metal
	76 Ni-16 Cr-7 Fe Alloy (Active)
	Nickel (Active)
	Silicon Bronze
	Copper
	Red Brass
	Aluminum Brass
	Admiralty Brass
	Yellow Brass
	76 Ni-16 Cr-7 Fe Alloy (Passive)
	Nickel (Passive)
	Silver Solder
	70-30 Cupro-Nickel
	Monel
	Titanium
	13% Chromium Steel Type 410 (Passive)
	18-8-3 Chromium Nickel Stainless Steel Type 316 (Passive)
	18-8 Chromium Nickel Stainless Steel Type 304 (Passive)
	Silver
	Graphite
	Gold
Cathodic End	**Platinum**

53450-2-2-T29

124

where foreign matter or moisture may accumulate because of improper drainage or disposal outlets, to structures underneath floor boards, and to faying surfaces. Special inspections must be made of areas where magnesium alloys are used.

6-31. *Dissimilar metals.* Areas where dissimilar metals are in contact must be closely inspected, since an electric current is generated and flows from one metal to the other. The current causes a chemical action which results in dissolution of one of the metals. Corrosion is accelerated when appreciable moisture is present between dissimilar metals. Leather, neoprene, soundproofing, and insulating materials can pick up and hold moisture, causing corrosion.

6-32. *Corrosion at spotwelds.* Corrosion at spotwelds is chiefly the result of the entrance and entrapment of corrosive agents between the layers of metal. Some of the corrosion may be caused originally by fabrication processes, but its progress to the point of skin bulging and spotweld fracture is the direct result of moisture and contaminant working its way through open gaps and seams. This type of corrosion will be first evidenced by corrosion products appearing at the crevices through which the corrosive agents enter. Corrosion may appear at other external or internal faying surfaces, but it is usually more prevalent on external areas. More advanced corrosive attack causes skin buckling and eventual spotweld fracture. Skin buckling in its early stages may be detected by sighting along spotweld seams or by using a straightedge. The only technique that can be used to prevent this condition is to keep potential moisture entry points, including gaps, seams, and holes created by broken spotwelds, filled with sealant.

6-33. *Piano type hinges.* This type hinge is frequently found on access doors, plates, leading edges, ailerons, trim tabs, etc. Some are actuated only at inspection periods. Regardless of location, this type should be inspected frequently. Corrosion of piano type hinges usually begins in the hinge-pinhole and propagates outside in exfoliation corrosion.

6-34. *Exhaust gas paths.* Areas exposed and contaminated by gases are highly susceptible to corrosion. These areas (external, inside nacelles, wing spars, flap wells, attaching angles, etc.) must receive thorough cleaning and inspection at frequent intervals.

6-35. *Wheel-wells, landing gear, dive brakes, and similar areas.* Landing gears are subjected to repeatedly higher stresses than any other part of an aircraft. The above areas are also exposed to mud, water, salt, gravel and other debris from runways during flight operations. Due to many complicated shapes, assemblies, fittings, and recesses, complete coverage by protective film is difficult. During inspection of these areas pay particular attention to the following trouble areas:

- Magnesium wheels, especially around boltheads, lugs, lockrings, wheel web areas, etc., for entrapped water and foreign materials.
- Exposed tubing, "B" nuts and ferrules, under clamps and tubing identification tapes, and hose covered with braided wire.
- Crevices between stiffeners, ribs, and lower skin surfaces.
- Exposed position indicator switches, springs, and electrical connectors and equipment.

6-36. *Heavy or tapered aluminum alloy skin surfaces.* Heavy or thick sections of heat-treatable aluminum alloys are susceptible to intergranular corrosion and exfoliation of the metal. When you inspect external skin surfaces, look for metal exfoliation, expecially around countersink fastener heads. Exfoliation will first be evident as a small raised bump under the surface or paint film.

6-37. **Types of Corrosion.** During the visual inspection, corrosion appears in many different outward signs of the corroded metal. Corrosion is cataloged and typed in many ways. For descriptive purposes, the types we discuss fall under these commonly accepted titles: Uniform etch, Pitting, Intergranular, Exfoliation, Galvanic, Stress, Concentration-cell, and Fatigue corrosion. The figures referenced for the different types of corrosion are sample illustrations from technical order 1-1-2 and are not to be relied upon as the only visible signs of corrosion.

6-38. *Uniform etch.* Corrosion of metals by uniform chemical attack is the simplest form of corrosion and occurs in the atmosphere or in liquids. It occurs frequently under normal conditions of exposure and is relatively uniform over the metal surface. The surface effect produced by most chemical attacks (as by an acid) is a uniform etching of the metal. On a polished surface, this type of corrosion is first seen as a general dulling of the surface and if allowed to continue, the surface becomes rough and possibly frosted in appearance.

6-39. Micro anode and cathode areas are involved; consequently, uniform etch corrosion is localized corrosion occurring consistently and uniformly over the surface of a metal. The rusting of iron, the tarnishing of silver, the fogging of nickel, and the high temperature oxidation of iron or stainless steels are typical versions of uniform etch. The discoloration or general dulling of metals created by exposure to elevated temperatures are not considered as uniform etch corrosion.

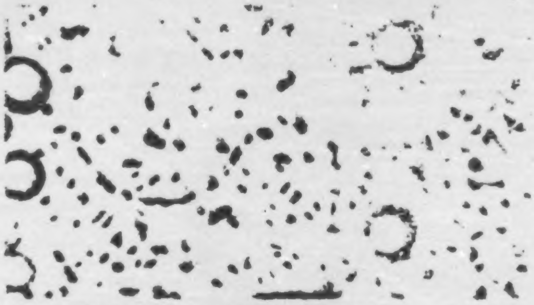
136

6-40. *Pitting.* This is the most common and severe form of localized corrosive attack on aluminum and magnesium alloys. Figures 11 and 12 show extracted samples of pitting corrosion on aluminum and magnesium found in TO 1-1-2. Thin metal sheets or plates are especially vulnerable to failure by this form of attack, since penetration of the metal at pit sites results in perforation of the metal and possibly results in unserviceability.

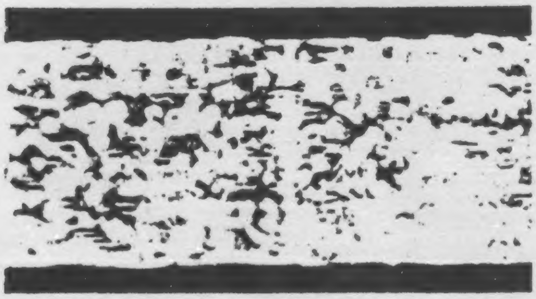
6-41. Pitting usually occurs in grain boundaries at highly anodic points on the metal surface. It is primarily the result of localized cell action. Pitting on aluminum alloys is first noticeable as a white or gray powdery deposit, similar to dust, which blotches the surface. When the deposit is cleaned away, tiny pits or holes are seen in the metal surface. Pitting corrosion also appears in other types of metal alloys.

6-42. *Intergranular.* This type corrosion occurs in boundaries between grains or crystals in metals. The boundary areas are usually anodic to the grains. Consequently, in certain corrosive electrolytes, if sufficiently wide potential differences exist between the anodic grain boundaries and the cathodic grains, rapid and concentrated intergranular or intercrystalline corrosion occurs.

EXAMPLE OF ATTACK



A - PITTING (CLAD MATERIAL)

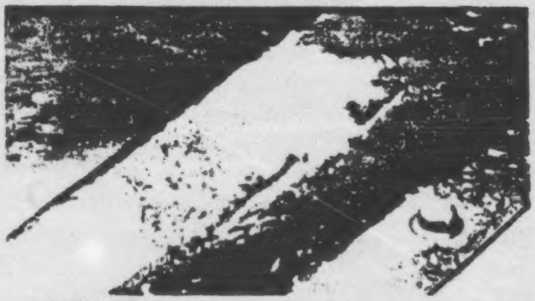


B - PITTING (NON-CLAD MATERIAL)

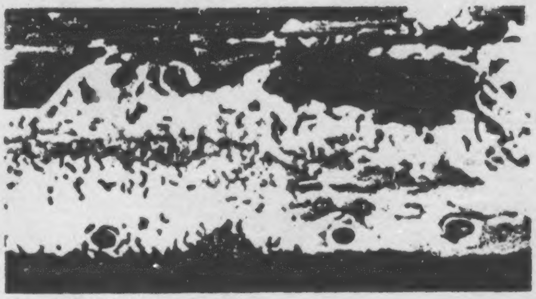
53450-2-2-2

Figure 11. Examples of pitting corrosion (aluminum).

EXAMPLE OF ATTACK



A - PITTING



B - SEVERE PITTING

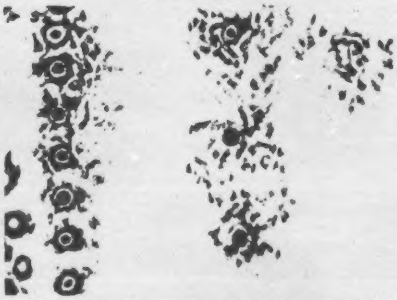
53450-2-2-3

Figure 12. Examples of pitting corrosion (magnesium).

6-43. Figure 13 shows an example of the external signs of intergranular corrosion on clad aluminum material. Figure 14 shows intergranular corrosion of 7075-T6 aluminum adjacent to a steel fastener. In this example, the grain boundaries are anodic to both the main body and the steel fastener.

6-44. Many metals are susceptible to some extent to intergranular corrosion; in many cases, this type of attack is of little significance. How-

EXAMPLE OF ATTACK



INTERGRANULAR (CLAD MATERIAL)

53450-2-2-4

Figure 13. Example of intergranular corrosion (clad aluminum).

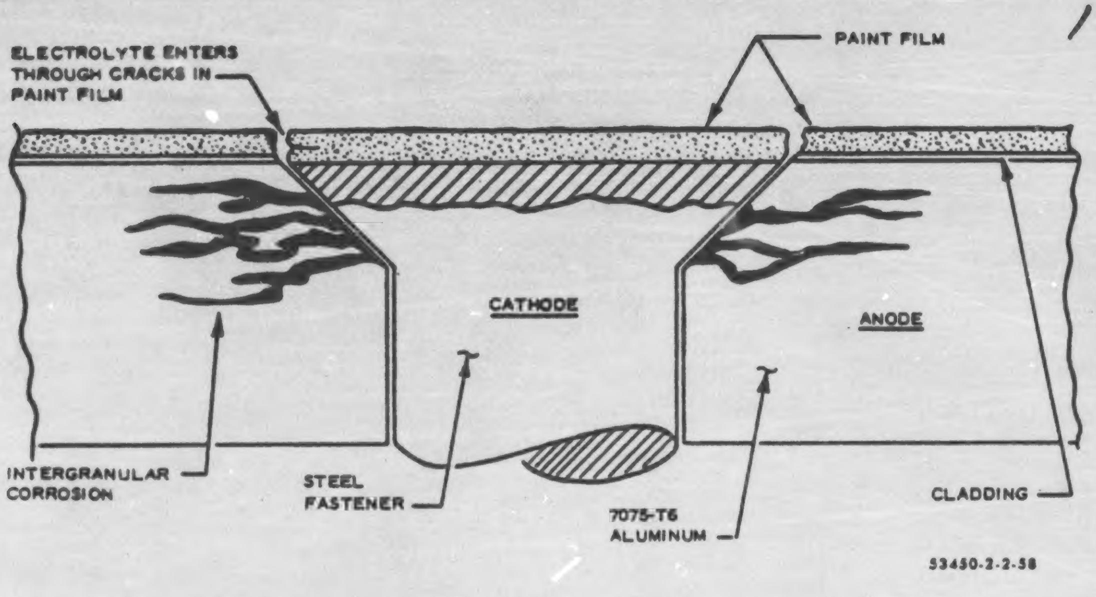


Figure 14. Intergranular corrosion of steel fastener and aluminum.

ever, when the corrosion attack at grain boundaries is severe, the strength and other physical properties of the metal may be reduced out of proportion to the amount of metal consumed.

6-45. Of the structural alloys, the so-called nonstabilized stainless steels are singularly vulnerable to intergranular corrosion. When these alloys are heated in the temperature range of 900° to 1500° Fahrenheit for a sufficient time, the carbon contained in the alloy will combine with chromium in the alloy to produce an iron chromium carbide which precipitates in the grain boundaries. This results in the lowering of chromium content of areas adjacent to the carbides. The chromium deprived protions of the alloy are susceptible to intergranular corrosive attack.

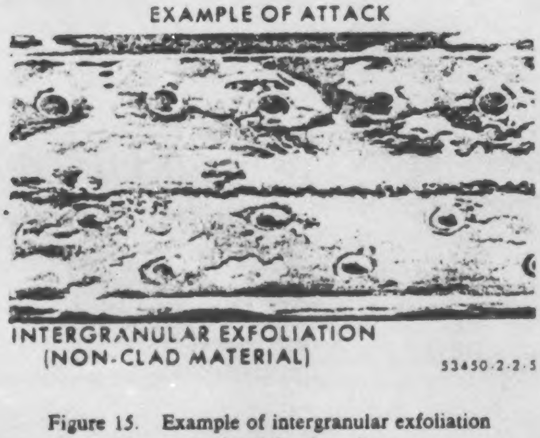


Figure 15. Example of intergranular exfoliation corrosion (aluminum).

6-46. This increased susceptibility of intergrandular corrosion through heating is frequently referred to as sensitization to intergranular corrosion. If not followed by proper solution annealing treatment, welded nonstabilized stainless steels may be sensitized to grain boundary corrosion attack in the heat affected zones on either sides of the weld.

6-47. *Exfoliation.* Exfoliation (see fig. 15) is a form of intergranular corrosion and shows itself by "lifting up" the surface grains of a metal by the force of expanding corrosion products occurring at the grain boundaries just below the surface. It is visible evidence of intergranular corrosion and is most often seen on extruded sections where grain thicknesses are usually less than in rolled forms of metal alloys.

6-48. *Galvanic.* Previously we discussed the galvanic series of metals and alloys illustrated in table 29. Galvanic corrosion occurs when dissimilar metals are in contact and external circuit is provided by the presence of moisture. It is usually recognizable by the presence of a buildup of corrosion at the joint between the metals. For example, aluminum and magnesium skins riveted together in an aircraft wing form a galvanic couple if moisture or contamination are present. When magnesium is attached with steel fasteners, galvanic corrosion can occur (see fig. 16). Metals grouped together in table 30 have no strong tendency to produce galvanic corrosion and are relatively safe to use in contact with each other.

6-49. The coupling of metals from different groups and distant from each other (table 30)

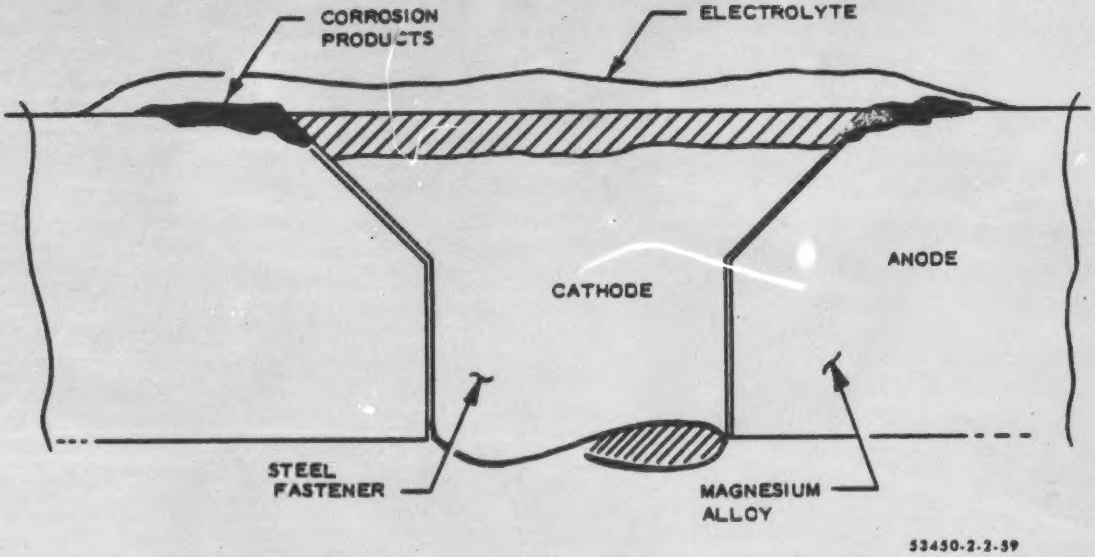


Figure 16. Galvanic corrosion of magnesium adjacent to steel fastener.

usually results in galvanic or accelerated corrosion of the metal higher on the list. The farther apart the metals are in the table (table 29) the greater is the galvanic tendency, as can be determined by measurement of the electric potential difference between them.

6-50. All commonly used metals will cause corrosion of magnesium in a strong salt environment. Cadmium or zinc plating on the more cathodic metals such as iron and steel will greatly reduce galvanic corrosion. It has been found that tin plated metal, when connected to magnesium, causes less corrosion than cadmium or zinc plated metal. This happens because, in this unusual circumstance, the tin polarizes and acts as an insulator. This is a contradiction of table 29; hence, it must be kept in mind that the galvanic series of metals and alloys is to be used for *general* information and that exceptions do exist.

6-51. *Stress.* Stress corrosion failure results from the combined effect of tensile stress and corrosion. Cold-working or straining, quenching (in heat-treatment), grinding, or welding may produce internal stresses. while applied stress

TABLE 30
GROUPING OF METALS AND ALLOYS

Group I	Magnesium and its alloys. Aluminum alloys 5052, 5056, 5356, 6061, and 6063.
Group II	Cadmium, Zinc, and Aluminum and their alloys (including the aluminum alloys in Group I).
Group III	Iron, Lead, and Tin and their alloys (except stainless steel).
Group IV	Copper, Chromium, Nickel, Silver, Gold, Platinum, Titanium, Cobalt, and Rhodium and their alloys; Stainless Steel and Graphite.

1. Metals classified in the same group are considered similar to one another.
2. Metals classified in different groups are considered dissimilar to one another.

53450-2-2-T30

may be local or uniform and static or cyclic. The most destructive type of stress is that which is local and nonuniform. Under such conditions, the stressed zones are subject to accelerated corrosion.

6-52. It is known that areas of metals which are subjected to applied stresses will develop a more anodic nature at such areas under corrosive conditions. Adjoining unstressed areas or less stressed areas will be less anodic or more cathodic.

6-53. Stresses induced when a piece is deformed, those induced by press and shrink fits, and those in rivets and bolts are internal stresses. Concealed stress is more important than design stress, because stress corrosion is difficult to recognize before it has overcome the design safety factor.

6-54. The magnitude of the stress varies from point to point within the metal. Stresses in the neighborhood of the yield strength are generally necessary to promote stress corrosion cracking; but failures have occurred at lower stresses.

6-55. *Fatigue.* Fatigue corrosion is a special case of stress corrosion caused by the combined effects of cyclic stress and corrosion. No metal is immune to some reduction of its resistance to cyclic stressing if the metal is in a corrosive environment. Damage from fatigue corrosion is greater than the sum of the damage from both cyclic stresses and corrosion.

6-56. Fatigue corrosion failure occurs in two stages. During the first stage, the combined action of corrosion and cyclic stresses damages the metal by pitting and cracking to such a degree that fracture by cyclic stressing will ultimately occur, even if the corrosive environment is completely removed. The second stage is essentially a fatigue stage in which failure proceeds by propagation of the crack and is controlled primarily by stress concentration effects and the physical properties of the metal.

6-57. Fracture of a metal part due to fatigue corrosion generally occurs at a stress far below the fatigue limit in laboratory air, even though the amount of corrosion is unbelievably small. For this reason, protection of all parts subject to alternating stress is particularly important, even in environments that are only mildly corrosive.

6-58. *Concentration-cell.* Localized accelerated corrosion attack caused by nonuniformity of the electrolyte or the environment is referred to as concentration-cell corrosion. The attack, which is electrochemical in nature, ensues because of differences in the concentration or ions or of dissolved gases (oxygen for example), resulting in differences of potential on the surface of the same metal or surfaces of electrodes consisting of the same metal. Differences in environment may result because of cracks or crevices on the metal surface which, because of reactions in confined spaces, deplete electrolyte constituents, such as oxygen-deficient cells at faying surfaces (see fig. 17).

6-59. When a metal goes into solution, there is some concentration of ions of that metal in the corroding solution. The lower the metal ion concentration, the greater the tendency for the metal to go into solution as the metal ions. When the concentration of metal ions in the solution reaches saturation, the metal does not dissolve. If the concentration of metal ions in the solution is greater at one point on that metal than at

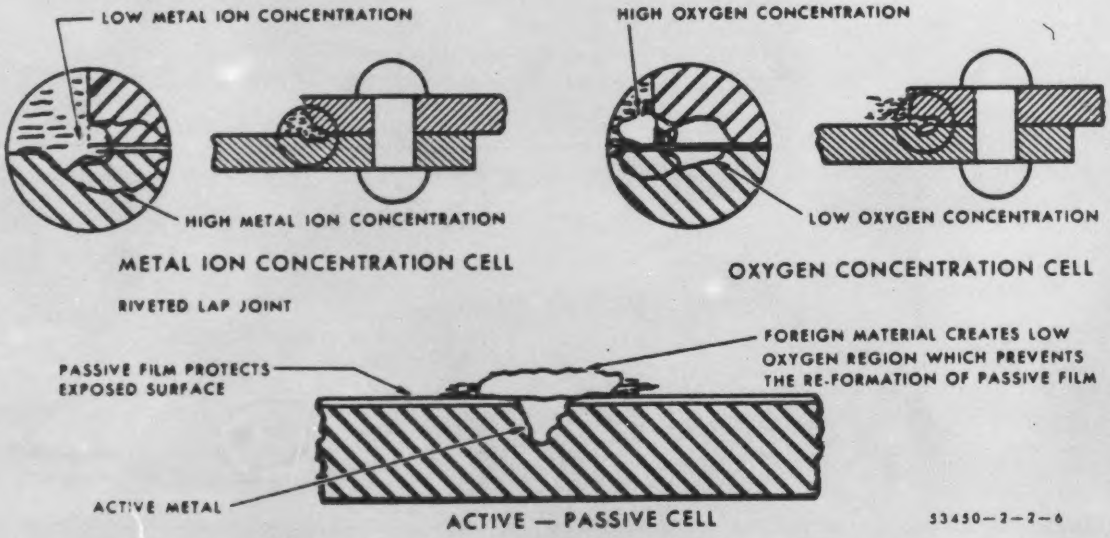

LOW METAL ION CONCENTRATION
HIGH METAL ION CONCENTRATION
METAL ION CONCENTRATION CELL
RIVETED LAP JOINT
HIGH OXYGEN CONCENTRATION
LOW OXYGEN CONCENTRATION
OXYGEN CONCENTRATION CELL
PASSIVE FILM PROTECTS EXPOSED SURFACE
FOREIGN MATERIAL CREATES LOW OXYGEN REGION WHICH PREVENTS THE RE-FORMATION OF PASSIVE FILM
ACTIVE METAL
ACTIVE — PASSIVE CELL
53450-2-2-6

Figure 17. Concentration-cell corrosion.

129

other, then concentration-cell action will occur. An electrical potential is established between the two points of different concentration; the metal surface in contact with the higher concentration of metal ions becomes the cathode, and the surface of the lower concentration is the anode. The flow of current is from the metal to the solution at the anode, and from the solution to the metal at the cathode. At the point of higher concentration, the cathode is protected, while at the point of lower concentration, the anode is attacked. In actual service, metal-ion concentration variation may be due to differences in velocity or agitation. The metals ions in the corrosion products may be removed from one part of a metal at a higher rate; or they may not be removed at all from one part of the metal. In either case, such sustained action would lead to differences in metal-ion concentration.

6-60. Corrosion by oxygen concentration-cells may occur when the concentration of dissolved oxygen is greater at one point on the metal than at another point. As in the case of metal-ion concentration, a difference in potential is established between the two points of differing oxygen concentration. The point of the metal of higher oxygen concentration is the cathode, whereas the point of surface of the lower oxygen concentration is the anode. The current flows from the metal to the electrolyte at the point of lowest concentration, and from the electrolyte to the metal at the point of highest concentration. This action results in accelerated corrosion at the area of lowest oxygen concentration in the cell.

6-61. In some metals it is possible for metal-ion and oxygen concentrations in the cell to counteract one another. The development of an area of higher oxygen concentration may result in an increase of metal ions in the area of the anode. This would produce another set of potential differences that would counteract the original effect. Oxygen-cell concentration corrosion would then be retarded. This peculiar pattern may occur with many metals, especially copper and copper alloys.

6-62. Active-passive cell action may arise with alloys that develop a protective, passivating type of film. If an oxygen-cell type of condition develops, the absence of oxygen at the anodic area will prevent the protective film from reforming. Because of the lack of sufficiency of the passivating (protective) film, corrosion at the exposed anodic areas is accelerated. This accelerated corrosion occurs because of the increased potential between the passive cathodic areas and the active sites.

6-63. Similar concentration action may be initiated where a part of the metal is shielded or covered by foreign matter or nonmetallic structural members. These circumstances will be especially effective in promoting pitting if the shielded part of the metal is a stagnant solution while the free area is in a rapidly moving solution. Crevices and cracks will similarly become potential anodic areas.

6-64. **Inspection Procedures.** Previously we discussed the factors which produce corrosion, the basic causes of corrosion, the appearance, and the effects on metal that corrosion takes. We also discussed the typical areas where accululation of dirt and moisture tend to collect and create corrosion potential.

6-65. On occasion you will be called to assist the APG (airplane general) mechanic and corrosion control personnel during a corrosion inspection of an aircraft. Each aircraft has four basic areas to be inspected: wings, fuselage exterior, empennage, and fuelage interior. There are many procedures for inspection. One typical procedure is to start at the wing tips. Survey the leading edge of the wing, working from outboard at the tip, inboard to the fuselage, and then inspect the trailing edge, being especially observant of niches or *natural wells*, such as attachment points of control surfaces, flaps, ailerons, spoilers, etc., where foreign matter will collect. After you have inspected the upper surface, inspect the lower surface of the wing, checking ribs, brackets, and all natural wells. Keep in mind the different forms that corrosion takes from uniform etch to intergranular exfoliation. After you inspect the wings, start at the nose of the aircraft and progressively inspect the areas we previously discussed (wheel wells, spotwelds, fasteners, piano type hinges, etc.), to the tail of the aircraft, first working the right side then the left.

6-66. Being systematic is the key to a complete inspection. Some aircraft inspection workcards are being changed at this time to an incorporated corrosion inspection which is based primarily on this systematic type of inspection. After the fuselage, the empennage is inspected with the same systematic thoroughness as the wings.

6-67. Once the exterior of the aircraft has been satisfactorily inspected, the internal portion is inspected, giving rest and relief areas special attention along with battery storage areas due to the corrosive properties of the materials in these areas. All *well forming* brackets, drain hole areas, bulkheads, and other moisture accumulation areas must be scrutinized from the prevention aspect as stated previously. You can eliminate many major and repetitious repairs by correct and early detection and correction through inspection. Inspection and recognition comprise the first stage of corrosion control; documentation is also a vital part of this procedure.

6-68. You are aware that specific entries are required on the AFTO Form 781A. Maintenance Discrepancy/Work Record, of the aircraft historical records (AFTO 780 series). When corrosion cannot be corrected at the time of inspection of an aircraft, an entry must be made in the aircraft forms. The symbol block must be completed indicating the seriousness of the discrepancy (red X or red diagonal). If the corrosion is of such extent as to jeopardize the safety of the aircraft (intergranular exfoliation in a main structural member, etc.), and could create a safety of flight factor, a red X is entered. For corrosion discovered, such as etch, pitting, etc., in a noncritical area, of a minor correctable nature, a red diagonal entry is made, as this is the symbol for minor discrepancies not of a safety nature.

6-69. After the proper symbol is determined and entered on the AFTO Form 781A, the date the discrepancy was discovered is entered in the date discovered (Date Discd) block. The discrepancy block should contain the type of corrosion discovered and the location. This should be pinpointed by the station number location. The name of the corroded item, if so identifiable, should also be given, as for example: galvanic corrosion on rib, right wing, station 623, 7 inches aft of rear spar. When the discrepancy has been entered clearly and completely, the person discovering the corrosion enters his first name initial, last name and rank in the Discovered By block.

6-70. Before you continue to Section 7, turn to the workbook and answer exercises for Section 6.

7. Corrosion Prevention

7-1. Having discussed the cause and effect of corrosion on aircraft metals let us consider what we can do to eliminate corroded parts and how we are responsible for preventing and eliminating corrosion.

7-2. Corrosion prevention involves basically the same procedures or steps for all metals, but differences in equipment and chemicals necessitate different applications. These steps include but are not limited to:

- Metal identification
- Cleaning
- Chemical mixing
- Treating
- Priming
- Application of the protective finish
- Documenting the maintenance actions

7-3. **Safety.** Before we discuss the basic preventive processes involved in corrosion control, a refresher on the safety precautions involved in handling, mixing, and storage of cleaners and acids is in order. In the previous volume, the importance of ground safety for equipment and personnel was stressed. However, when you work with corrosion prevention and control, take care to protect yourself and coworkers from health hazards. Our medics call this "preventive medicine." It is most important that you use cleaning materials and application equipment for the purposes intended and in the manner prescribed in applicable TOs. Special emphasis should be placed on the use, handling, and storage of chemicals and solvents used in cleaning and corrosion control.

7-4. *Dust.* Dust is a prime source of contamination of man and machines. It is ever present on earth and in atmosphere resulting from chemical, biological, or physical change induced by man and nature. In turn, men and machines contaminate and pollute the atmosphere and earth with gases, vapors, liquids, and solids. Caught up in the wind and rain, dust can precipitate or fall out from our surrounding atmosphere and be distributed over a wide area in a variety of compounds. Most of us are familiar with nuclear fallout which results in radioactive dust (dust impregnated with radioactive materials) which may drift, be scattered by the winds, precipitate, or be collected on aircraft flying through a contaminated area. Similarly, we often pollute our immediate surroundings with gases, vapors, and liquids saturated with harmful dust particles which attack the human body causing pain, irritation, nausea, deterioration, and death. Dust of dry acids and compounds such as chromic acid, sodium dicromate, and ammonium bifluoride cause ulceration of the mucus membranes and the skin. When breathed into the respiratory system, they combine with body fluids to produce severe results. Dust that has settled or collected on the skin may react in dry state or combine with moisture to cause irritation or deterioration of the skin.

7-5. *Gas.* A gas is a substance which exists as a gas in its normal state at normal temperatures and pressures. A vapor is the gas given off from a substance which normally exists as a liquid, and in some cases as a solid. Both gases and vapors vary in weight from heavier to lighter than air. Depending on their relative density, they will settle to the floor or rise to the ceiling and diffuse throughout the room atmosphere. Gases and vapors can be divided into four groups, depending on their effects on the body.

- Asphyxiants
- Irritants
- Anesthetics
- Poisons

/31

7-6. *Asphyxiants.* Asphyxiants are gases or vapors that prevent a person's blood from absorbing the oxygen needed for life through the lungs. These gases and vapors replace the oxygen in the air that is breathed. Methanes, other hydrocarbons, hydrogen, nitrogen oxide, acetylene, and the inert gases are common asphyxiants. Chemical asphyxiants such as cyanogen compounds and carbon monoxide prevent the human blood from absorbing oxygen by filling the blood with excessive amounts of the asphyxiants.

7-7. *Irritants.* Irritant gases and vapors cause inflamnation of the respiratory system. Complications such as pneumonia or other pulmonary diseases may result from injuries caused by exposure to such irritating gases and vapors as ammonia, chlorine, sulphur dioxide, hydrogen sulfide, hydrochloric acid, nitrogen oxides, and phosphorus and arsenic trichloride. Not only are the vapors of these gases hazardous as irritants, but they may be toxic as well.

7-8. *Anesthetics.* Anesthetic gases and vapors have a narcotic or druglike effect on persons. Their presence may cause the central nervous system to be dangerously depressed, and respiratory failure may occur, resulting in death. Practically all narcotic gases and vapors belong to the hydrocarbon series and include formaldehyde, methyl ether, ethyl ether, gasoline, naptha, benzine, dimethyl ketone, methyl acetate, ethyl acetate, carbon tetrachloride, and other related substances.

7-9. *Poisons.* Poisonous gases and vapors act directly on the body, injuring or destroying visceral organs, the body's blood-forming system, tissues, or bones, depending on the type of gas or vapor involved. Methyl chloride, methyl bromide, ethyl chloride, ethyl bromide, certain alcohol compounds, tetraethyl lead, and others are all sources of poisonous gases and vapors.

7-10. *Fumes.* Fumes are particles usually resulting from the condensation of substances that have been heated or burned. They are produced from chemical or metallurgical processes, molten metal, or by decomposition. The term "fume" is often misused by people who think of it in terms of gases and vapors. Fumes present health hazards in many ways, depending upon their source. The fumes produced from metals such as lead, zinc, cadmium, and manganese are particularly harmful. These fumes may not be present during normal working conditions, but can be created by combining various substances. For example, if a piece of zinc is placed into a container of hydrochloric acid, the zinc displaces the hydrogen in the acid. The hydrogen, being lighter than air, will rise in the form of gas, and it is not only an asphyxiate but is also explosive. Alodine, used as a chromate treatment for aluminum, can become spontaneously ignited if left on rags and brushes.

7-11. It is very important that only authorized mixtures of substances be made, and that only authorized, trained personnel be allowed access to corrosion control chemicals.

7-12. Most paint removers have an alkali base. These are very caustic materials which will burn the skin upon contact. Most serious accidents involving paint removers occur while the container is being opened. Heat causes the paint remover to expand in the container, and when the cap is removed, the contents are forced out violently. To prevent serious injury and loss of eyesight, always make sure the container has cooled prior to opening if it has been stored in a warm atmosphere. Place the opening of a container at the uppermost point before opening, and always wear a protective face mask and clothing to insure maximum safety.

7-13. Safety equipment or safety items worn by personnel involved in the use of corrosion chemicals and acids include rubber gloves, aprons, boots, and face shields. When you work in the shop, insure that the area is equipped with ventilating fans and hoods, emergency shower, eye wash fountain, and fire extinguishers. Remember that safety equipment, though effective, is useless if not properly used. Keep your safety equipment clean and in proper working order. A dirty face shield or a leaking glove defeats its own purpose.

7-14. **Storage, Handling, and Use of Chemicals.** Proper storage of corrosion control chemicals is necessary to prevent possible fires, injury to personnel, and to prevent freezing of some materials. Acids must be stored away from any ignition sources and in carboys (special constructed containers for acids and chemicals), and separated from each other. This is to prevent breakage of containers which could cause ignition due to contact of acids and organic materials. Solvents and paint removers should be stored at room temperature to prevent freezing and rupture of the containers due to heat expansion.

7-15. Handling of acids is hazardous. Pouring should be done with the aid of a tilter or siphon. If a siphon is used, the fluid flow should be started by using a rubber squeeze bulb. *Never add water to acid.* Remember to always add acid ("AAA," *A*lways *A*dd *A*cid) to water. If water is poured into acid, an explosion may result. When working with acids and chemicals, keep all the floors clear of obstacles to prevent tripping. When using chemicals and acids, replace the container caps immediately after use. Maintain a businesslike atmosphere wherever

TABLE 31

TYPICAL CORROSION REMOVAL AND TREATMENT PROCEDURES FOR ALUMINUM ALLOYS

TYPE OF CORROSION	STEP 1 CLEANING TO REMOVE FOREIGN MATTER	STEP 2 PAINT STRIPPING (WHEN APPLICABLE)	STEP 3 CORROSION REMOVAL	STEP 4 SURFACE TREATMENT (WHEN APPLICABLE)
Light or heavy pitting or etching of aluminum (clad)	Remove foreign matter with cleaner, Spec MIL-C-25769	Readily accessible areas: Strip with stripper, Spec MIL-R-25134 Confined areas: Strip with solvent	Remove corrosion with brightener, Spec MIL-C-25378	Chromate conversion coating, Spec MIL-C-5541
Light or heavy pitting or etching of aluminum (non-clad)	As above	As above	Remove corrosion by mechanical method -or- Remove corrosion with brightener, Spec MIL-C-25378	As above
Intergranular or exfoliation corrosion of aluminum	As above	As above	Remove corrosion by mechanical method (ref para 5-17)	As above
Light or heavy corrosion on small aluminum parts which can be removed for treatment	Painted Parts Clean and strip in solution of paint and varnish remover, Spec MIL-R-7751 Unpainted parts Clean with compound, Spec P-C-426, MIL-C-5543, or vapor degrease	Not Required If cleaning accomplished with paint and varnish remover, Spec MIL-R-7751	Remove corrosion and oxide film by immersion of parts in phosphoric-chromate acid solution	Immersion chromate conversion coating, Spec MIL-C-5541
Stress corrosion cracking of aluminum	Not Applicable Replace or repair defective part as required in applicable -3 technical order	See Step 1	See Step 1	See Step 1

53450-2-2-T31

chemicals are used. Horseplay is deadly, and has no place during corrosion control operations. After using the equipment, rinse all rags and brushes in water to prevent spontaneous combustion. Where proper operating techniques of equipment and ground safety precautions are observed, accidents are greatly reduced.

7-16. When you work around acids and other chemicals, you must have some knowledge of first aid, and especially artificial respiration. If a person has been asphyxiated, provide fresh air and apply artifical respiration if necessary. In the case of spillage of chemicals on your person, spray with plenty of water for approximately 15 minutes. Obtain medical attention immediately. *Do not* try to neutralize acid on the body or in the eyes with baking soda.

7-17. **Aluminum.** Aluminum and alloys of aluminum are the most widely used materials in aircraft construction. Aluminum appears high in the electrochemical series of elements, which we discussed in the preceding section, and its position indicates that it should corrode very easily. However, the formation of a tightly adhering oxide film offers increased resistance in most corrosive conditions. Most metals in contact with aluminum form couples which undergo galvanic attack. Aluminum alloys are subject to pitting, intergranular corrosion, and stress corrosion cracking. In some cases, the corrosive products of metal in contact with aluminum are corrosive to aluminum; therefore, it is necessary to clean and protect aluminum and its alloys. Table 31 outlines typical procedures for treating aluminum alloy parts and assemblies for aircraft or missile systems. This table provides for corrosion removal by either mechanical or chemical methods and immersion treatment of small parts. The following paragraphs contain additional information on this subject.

7-18. *Cleaning.* If the corroded area of aluminum material is soiled by grease, dirt, or other foreign materials, it is necessary to clean the area prior to any paint stripping or corrosion removal. There are two principal ways of cleaning aluminum material. One way is applicable to parts that cannot be logically removed from a larger component (a skin section on an aircraft) and the other procedure is used for parts that can be removed.

7-19. Parts that cannot be removed are cleaned with an alkaline water-base cleaner (Military Specification MIL-C-25769, Type II (powder). On painted and unpainted surfaces, dissolve one 5-pound package for each 10 gallons of water. Agitate thoroughly with a wooden paddle to insure the powder is properly mixed.

7-20. The solution is applied either by spraying or with a mop, sponge, or brush. Allow the solution to remain on the surface for several minutes while you brush the surface thoroughly. After you have sufficiently brushed the solution onto the surface rinse off the solution completely with a spray or stream of water. Do not allow the compound to dry before rinsing, as less effective cleaning will result.

7-21. On parts that can be removed and cleaned on an individual basis one of the following procedures of cleaning by immersion, spray, or vapor cleaning is practical.

7-22. Immersion cleaning with cleaning compound Federal Specification P–C–436 is accomplished by first dissolving 10 to 12 ounces of the cleaning compound in each gallon of water in a mild steel tank. Then the solution is applied at a temperature of 200° to 212° Fahrenheit. Immersion time varies with the types of soils to be removed. Generally, lubricating oil type soils require approximately 5 minutes' immersion with some agitation during the immersions. Asphaltic type soils may require 20 to 30 minutes' immersion, depending on the thickness of the soil involved.

7-23. Immersion cleaning and paint removing can be done with paint and varnish remover Military Specification MIL–R–7751. Prepare the solution by adding 3 to 5 ounces of Specification MIL–R–7751 to each gallon of water. Dissolve the compound in one-fifth of the required volume at 190° Fahrenheit or above. Allow the solution to stand overnight, then add the balance of the water at room temperature. Application temperature of this solution is between 190° and 212° Fahrenheit. Presence of dissimilar metals in the tank at the same time must be avoided. All work is to be kept below the solution surface during the treating time. Treating time should be no longer than necessary to complete the required cleaning, and in no case should the parts remain in the solution tank for more than 1 hour longer than required to remove the finish or soils.

7-24. Washing machine compound Specification MIL–C–5543 is used for spray washing metal parts. This compound is for use in industrial spray machines for the removal of corrosion preventive compounds, oils, and grease from steel, brass, aluminum, and magnesium parts. The recommended concentration is 1 ounce per gallon of water. Steam cleaning compound, Federal Specification P–C–437, may be substituted if MIL–C–5543 is not available. The addition of small quantities of kerosene, Federal Specification VV–K–211, may be added to these solutions if excessive buildup of foam occurs during operation.

7-25. In addition to alkaline water-base cleaners, vapor degreasing may be used for immersion cleaning and spray washing cleaning. Vapor degreasing may be accomplished with trichloroethylene, Specification MIL–T–7003 (aircraft parts) or with trichloroethylene, Specification MIL–T–27602 (aircraft or missile parts).

7-26. *Paint stripping.* After the surface to be treated has been thoroughly cleaned, the next step is to remove any remaining surface finish such as paint or primer. The way the finish is removed depends upon the accessibility of the area and the degree and type of corrosion.

7-27. Chemical paint stripping of readily accessible areas is accomplished by masking all faying surface, seams, access doors, or other openings, using masking tape and barrier paper. Low adhesion, Specification MIL–S–8784, Class B, material may be used to protect seams when stripping paint from aircraft. A small bead of Specification MIL–S–8784, Class B, material extended over all seams prevents entry of paint stripper, eliminating the possibility of corrosive action. Allow MIL–S–8784 material to cure to a firm rubbery state prior to the stripping operation. The fillets formed by Specification MIL–S–8784 material are to be peeled off by hand after completion of the stripping operation.

CAUTION: Paint remover has a detrimental effect on the strength of adhesives. Failure to mask or seal joints, access doors, or other openings or panels which have been bonded with adhesives may cause failure of the adhesives.

WARNING: Observe personnel precautionary and protective measures. Use face shield when spraying. Prevent wind from blowing the stripper on personnel. If stripper is splashed into your eyes, immediately flush your eyes thoroughly with water and get medical assistance.

CAUTION: Prevent contact of paint stripper with acrylic rubber, lubricated parts, windows, canopies, and radomes. Keep stripper out of louvers and scoops not requiring stripping. The barrel, pump, hose, nozzle, etc., of the stripping equipment must be thoroughly rinsed with water immediately after use to neutralize any possible continuing corrosive effect of the stripper.

7-28. Apply water-emulsifiable, thickened paint stripper, Specification MIL–R–25134, with a long handle, nonmetallic brush. Other equipment needed and complete instruction for the removal of paint may be obtained in TO 1–1–8 and the specific aircraft manuals when needed.

7-29. If it is impractical to use emulsifiable stripper because of complexities of assembly and rinsing difficulties, paint may be removed in confined areas by using solvent materials. These are applied with a soft bristle brush or clean cloths. The materials include ethyl acetate, Federal Specification TT–E–751 or lacquer thinner, Federal Specification TT–T–266.

CAUTION: In areas of oxygen storage and transfer systems, use extreme caution when using ethyl acetate, lacquer thinner, or other solvents that are not oxygen compatible. Do not use the solvents on flanges, valves, or other components where there is a possibility of the solvent coming in direct contact with oxygen. In these areas use only dichloromethane, Specification MIL–D–6998, for paint stripping. Do not allow ethyl acetate, lacquer thinner, or dichloromethane to spread to adjacent areas not being treated, or to splash, overspray, or spill on adjacent elastomers (rubber, synthetic rubber, plastic, etc.), as deterioration of the elastomers will result.

WARNING: Dichloromethane is toxic. Provide adequate ventilation and avoid breathing of fumes. Avoid contact with skin by use of protective clothing. Use goggles or face shields to protect your face.

7-30. Allow the solvent to remain on the surface until all of the paint has softened and lifted. To keep the area wet with the solvent it may be necessary to keep a cloth saturated with solvent on the surface of the metal. Wipe off all solvent with a clean damp cloth, frequently rinsing the cloth in clear water. Repeat the application and removal of the solvent until all paint and residue have been removed from the metal surface, including recesses and the area around rivets, bolts, etc. After all paint and solvent have been removed wipe the area clean and dry with a clean, lint-free cloth.

7-31. *Corrosion removal.* The foremost consideration in removing corrosion products is that removal must be complete. Failure to clean away all residues lets corrosion continue even after the affected area is refinished. Areas to be treated for corrosion must be clean, unpainted, and free of oil and grease. Power-operated rotary files may be used with caution to remove corrosion from bulky or inaccessible members. You should avoid removing too much material when using this method, and you should carefully smooth and blend the filed areas. Consider the reduction in cross section because of corrosion removal when you determine if a part will require reinforcement in accordance with the structural repair manual or replacement to insure proper strength.

7-32. The mechanical removal method is recommended for corroded areas on all nonclad aluminum alloys such as that used in floor beams and stringer extrusions.

7-33. After the removal of all corrosion visible through a four-power or stronger magnifying glass, an additional 0.002 inch is removed to insure that absolutely no corrosion products remain.

7-34. Some of the equipment and the type of corrosion they remove include the following:

- Nonwoven, nonmetallic, abrasive mat for use in removing light corrosion products from extrusions, tubing, and ducts. (Do not use steel wool.)
- Carbide tipped scraper or fine fluted rotary file to remove heavy corrosion products.
- Air-powered drill or grinder and rubber grinding wheel to remove pitting and exfoliation or intergranular corrosion from aluminum alloy plates and sheets.

7-35. In removing corrosion by mechanical means, observe these precautions:

a. Always use goggles or face shield, as corrosion products can break loose and fly off.

b. Don't use carbon steel brush or carbon steel wool on aluminum surfaces. Tiny dissimilar metal particles will become embedded in the aluminum and cause further corrosion and subsequent damage to the equipment.

c. Use only aluminum oxide abrasive wheels on aluminum.

d. Blend the surface of the reworked area smoothly and evenly with the surrounding original surface to eliminate stress concentration.

e. Do not use abrasive grinding or wire brushing on aircraft skin thinner than 0.0625 inch. Vigorous, heavy, continuous rubbing can generate enough heat to cause a metallurgical change.

7-36. To chemically remove corrosion products from clad aluminum alloys, metal conditioner and brightener, Specification MIL–C–25378, is used. When you work with any acid solution in the chemical removal of corrosion, keep the acid confined to the area being treated and off the surrounding areas. Always keep acid away from operating mechanisms, magnesium, and plated steel parts. This can be done by covering the nearby area with waterproof paper and masking tape. Keep a wet rag at hand and immediately remove any acid splash. This acid is primarily intended for the removal of corrosion from clad aluminum parts, but it can be used to remove corrosion products from nonclad aluminum alloys (stringers, sinks, ribs in wings, aluminum tubing, etc.). Take particular care to keep acid etchant out of faying surfaces. Do not spray chemical into internal structures. The wipe-on and wipe-off technique is recommended for ducting, tubing, stringers, and similar parts if followed by a thorough rinsing of the treated area with clear water.

7-37. Metal conditioner and brightener, Specification MIL–C–25378, is for use only on aluminum alloys. It is not used on or rinsed over magnesium. It is for use on aircraft skins only when required to remove corrosion.

7-38. As a precautionary measure, when using acid solution, always wear acid-resistant gloves, protective mask, and protective clothing.

7-39. The following are approved procedures for the removal of corrosion by the metal conditioner method:

a. Mask off nonclad aluminum, plated steel, and magnesium, as well as cracks and faying surfaces, to keep the metal conditioner from contacting these areas.

b. Apply metal conditioner and brightener, Specification MIL–C–25378, to the corroded area of clad aluminum alloy by using a brush or cloth.

c. For corrosion removal on small areas where a thickened metal conditioner and brightener is required, use Pasa-Jell Nr. 102 (aluminum type).

d. With a short fiber or aluminum brush (or abrasive mat), agitate the areas of deep pitting until all corrosion products are removed. Pay particular attention to areas around rivet heads and to butt joints of skins.

e. Sponge acid material with a damp cloth rinsed frequently in water Never leave conditioner in contact with the surface for more than 30 minutes.

f. Repeat the process as necessary, concentrating on the pitted areas until all corrosion is removed. The bottom of each pit should appear bright, and the metal should be uniformly etched. Questionable areas should be checked with a four-power or stronger magnifying glass.

g. After all corrosion has been removed, thoroughly rinse the treated area with clean water.

7-40. *Protective finishes.* Certain areas of an aircraft may require a paint finish after the corrosion has been removed. Table 32 outlines the various type systems, wash primers, the undercoat primers, and top coat requirements for the various types of finishes and contains remarks relating to the different finishes.

7-41. **Titanium.** Titanium and titanium alloys find numerous uses in aircraft and missiles, particularly where high temperatures (1000° Fahrenheit) are encountered. Even at high temperatures titanium retains its strength. Oxides will form on titanium when the metal is heated, as discussed previously in our section on metals. A

TABLE 32

TYPICAL FINISH SYSTEMS FOR ALUMINUM AND MAGNESIUM ALLOYS

TYPE SYSTEM	WASH PRIMER	PRIMER	TOP COAT	REMARKS
Acrylic-Nitro-Cellulose Lacquer	MIL-C-8514 or MIL-C-15328	MIL-P-7962	MIL-L-19537 (Gloss) or MIL-L-19538 (Camouflage)	General purpose exterior protective coating. Particularly resistant to diester lubricating oil.
Alkyd-Cellulose Nitrate Lacquer	As Above	MIL-P-8585	MIL-L-7178	General purpose exterior protective coating.
Vinyl-Alkyd	As Above	MIL-P-15930	MIL-P-15932 (Gloss Black) or MIL-P-15933 (Dull Black) or MIL-P-15934 (Gray No. 7) or MIL-P-15935 (Gray No. 11) or MIL-P-15936 (Gray No. 27)	For use on ground or airborne equipment where temperature does not exceed 200°F. Good moisture and acid resistance. Used in latrine and other areas where increased corrosion protection is required.
Alkyd Enamel	As Above	MIL-P-8585	MIL-E-7729 (Gloss) or TT-E-489 (Gloss) or TT-E-529 (semi-gloss) or TT-E-527 (Lusterless)	MIL-E-7729 enamel is normally used for aircraft applications, and TT-E-489, TT-E-529 and TT-E-527 enamels are for ground equipment
Polyurethane	As Above	MIL-P-27316	MIL-P-27227	Thermal reflective coating for aircraft application.

53450-2-2-T32

blue oxide coating will form at 700° to 800° Fahrenheit; a purple oxide will form at 800° to 950° Fahrenheit; and a gray or black oxide will form at 1000° Fahrenheit or higher.

7-42. Table 33 outlines typical procedures for treating titanium parts and assemblies. The table provides for corrosion removal by either mechanical or chemical methods.

7-43. *Cleaning.* If the corroded area is soiled by grease, dirt, or other foreign materials, it is necessary for you to clean the area prior to any paint stripping or corrosion removal. Painted or unpainted surfaces that can't be cleaned by immersion, spray, or vapor cleaning should be cleaned with alkaline water-base cleaner, Specification MIL-C-25769, or with dry cleaning solvent Federal Specification P-S-661, Type II, prior to paint stripping or corrosion removal. The mixing and cleaning procedures are the same as for aluminum, which was discussed earlier.

7-44. If either immersion spray or vapor cleaning is practical for cleaning individual parts, you should observe these procedures:

a. Immersion clean with cleaning compound Federal Specification P-C-436 (reference aluminum cleaning).

b. Immersion clean and strip paint in paint and varnish remover Specification MIL-R-7751 (reference aluminum cleaning).

c. Spray wash with compound, Specification MIL-C-5543 or Federal Specification P-S-751 (reference aluminum cleaning).

d. Vapor degrease with trichloroethylene, Specification MIL-T-7003 (aircraft parts), or Specification MIL-T-27602 (aircraft or missile parts).

7-45. *Paint stripping.* If paint is present, it is necessary to remove it prior to corrosion removal. This is done mechanically or chemically. The removal method depends upon accessibility of the area and the degree of corrosion. Mechanical stripping, such as sanding with abrasive paper, often removes the paint and the corrosion.

7-46. Chemical paint stripping in readily accessible areas may be accomplished by stripping paint with thickened paint stripper. Specification MIL–R–25134. The procedure for using the stripping material on titanium is the same as previously discussed for stripping aluminum alloys.

7-47. Chemical stripping in confined locations may be done with paint solvents such as ethyl acetate, Federal Specification TT–E–751, and lacquer thinner, Federal Specification TT–T–266, by using the same application procedures used on the aluminum alloys.

7-48. *Corrosion removal.* Corrosion can be removed from titanium by either mechanical or chemical means. Frequently both methods must be used to remove heavy scale from titanium. Mechanical corrosion removal includes standard procedures such as wire brushing with a stainless steel wire brush, sanding with aluminum oxide abrasive paper, and light abrasive blasting. In all cases, the metal surface must be cleaned following corrosion removal to insure that the metal surface is left free of foreign matter which could induce corrosion. A final protective paint or other finish may be applied if required.

7-49. Chemical corrosion may be removed by using an acid pickle, which removes most oxide coatings from titanium provided the scale was formed at temperatures below 1000° Fahrenheit. Gray or black oxides should be removed by a mechanical method, such as abrasive blasting, prior to the acid pickle to prevent pitting of the titanium. Titanium is susceptible to hydrogen embrittlement in acid solutions; therefore, the acid pickle should be used only when other corrosion removal methods are not adequate. You should follow these procedures for removing corrosion:

a. Remove soil by vapor degreasing or other cleaning method.

b. If present, remove gray or black oxide by mechanical means.

c. Immerse parts in a solution normally containing 20 percent nitric acid, 3 percent hydrofluoric acid, and 77 percent water, all by volume. Maintain the solution at normal room temperature. Allow the parts to remain in the solution only long enough to remove the oxide coats. Intermittent wiping with a brush or cloth during the pickling operation will facilitate oxide removal with a minimum of pitting.

TABLE 33

TYPICAL CORROSION REMOVAL AND TREATMENT FOR TITANIUM ALLOYS

TYPE OF CORROSION	STEP I CLEANING TO REMOVE FOREIGN MATTER	STEP II PAINT STRIPPING (WHEN APPLICABLE)	STEP III CORROSION REMOVAL
Light or heavy oxide on parts where mechanical corrosion removal methods are practical	Wipe area with solvent, Spec P-S-661, Type II, or alkaline water base cleaner, Spec MIL-C-25769	In readily accessible areas, strip paint with stripper, Spec MIL-R-25134, or in confined locations, use solvent, Spec TT-E-751	Remove corrosion with stainless steel wire brush, abrasive paper, or light abrasive blasting
Light or heavy oxide on parts where acid pickling is practical	Vapor degrease with trichloroethylene, Spec MIL-T-27602, or clean by other suitable method	As above. Paint can also be removed by immersion in paint and varnish remover, Spec MIL-R-7751	(1) Remove gray or black oxide by mechanical method as above. (2) Remove remaining oxide by immersion in nitric-hydrofluoric acid solution

53450-2-2-T33

removal method depends upon accessibility of the area and the degree of corrosion. Mechanical stripping, such as sanding with abrasive paper, often removes the paint and the corrosion.

7-46. Chemical paint stripping in readily accessible areas may be accomplished by stripping paint with thickened paint stripper, Specification MIL-R-25134. The procedure for using the stripping material on titanium is the same as previously discussed for stripping aluminum alloys.

7-47. Chemical stripping in confined locations may be done with paint solvents such as ethyl acetate, Federal Specification TT-E-751, and lacquer thinner, Federal Specification TT-T-266, by using the same application procedures used on the aluminum alloys.

7-48. *Corrosion removal.* Corrosion can be removed from titanium by either mechanical or chemical means. Frequently both methods must be used to remove heavy scale from titanium. Mechanical corrosion removal includes standard procedures such as wire brushing with a stainless steel wire brush, sanding with aluminum oxide abrasive paper, and light abrasive blasting. In all cases, the metal surface must be cleaned following corrosion removal to insure that the metal surface is left free of foreign matter which could induce corrosion. A final protective paint or other finish may be applied if required.

7-49. Chemical corrosion may be removed by using an acid pickle, which removes most oxide coatings from titanium provided the scale was formed at temperatures below 1000° Fahrenheit. Gray or black oxides should be removed by a mechanical method, such as abrasive blasting, prior to the acid pickle to prevent pitting of the titanium. Titanium is susceptible to hydrogen embrittlement in acid solutions; therefore, the acid pickle should be used only when other corrosion removal methods are not adequate. You should follow these procedures for removing corrosion:

a. Remove soil by vapor degreasing or other cleaning method.

b. If present, remove gray or black oxide by mechanical means.

c. Immerse parts in a solution normally containing 20 percent nitric acid, 3 percent hydrofluoric acid, and 77 percent water, all by volume. Maintain the solution at normal room temperature. Allow the parts to remain in the solution only long enough to remove the oxide coats. Intermittent wiping with a brush or cloth during the pickling operation will facilitate oxide removal with a minimum of pitting.

TABLE 33

TYPICAL CORROSION REMOVAL AND TREATMENT FOR TITANIUM ALLOYS

TYPE OF CORROSION	STEP I CLEANING TO REMOVE FOREIGN MATTER	STEP II PAINT STRIPPING (WHEN APPLICABLE)	STEP III CORROSION REMOVAL
Light or heavy oxide on parts where mechanical corrosion removal methods are practical	Wipe area with solvent, Spec P-S-661, Type II, or alkaline water base cleaner, Spec MIL-C-25769	In readily accessible areas, strip paint with stripper, Spec MIL-R-25134, or in confined locations, use solvent, Spec TT-E-751	Remove corrosion with stainless steel wire brush, abrasive paper, or light abrasive blasting
Light or heavy oxide on parts where acid pickling is practical	Vapor degrease with trichloroethylene, Spec MIL-T-27602, or clean by other suitable method	As above. Paint can also be removed by immersion in paint and varnish remover, Spec MIL-R-7751	(1) Remove gray or black oxide by mechanical method as above. (2) Remove remaining oxide by immersion in nitric-hydrofluoric acid solution

53450-2-2-T33

NOTE: The procedures for the use of these cleaning materials are the same as those previously covered in the cleaning of aluminum and aluminum alloys.

7-58. *Paint stripping.* After the surface under treatment has been thoroughly cleaned, the next step is to remove any remaining surface finish, such as paint or primer. This can be done mechanically or chemically. Removal with steel and other material depends upon the accessibility of the area and the degree and type of corrosion. Mechanical stripping such as abrasive blasting, grinding, chipping, sanding, wire brushing, etc., in most cases removes the corrosion.

7-59. In readily accessible areas, chemical paint stripping is accomplished with thickened paint stripper, Specification MIL–R–25134, used in the same manner as was discussed with aluminum and aluminum alloys.

7-60. Also using the same procedures as with aluminum alloys, ferrous metals other than stainless steel may be stripped of paint by using solvents such as ethyl acetate, Federal Specification TT–E–751, and lacquer thinner, Federal Specification TT–T–266.

TABLE 35

TYPICAL CORROSION REMOVAL AND TREATMENT PROCEDURES FOR FERROUS METALS OTHER THAN STAINLESS STEEL

TYPE OF CORROSION	STEP 1 CLEANING TO REMOVE FOREIGN MATTER	STEP 2 PAINT STRIPPING WHEN APPLICABLE	STEP 3 CORROSION REMOVAL
Light or heavy rust on structural parts or assemblies such as beams, columns, panels, brackets, gussets, racks, cases and housings	Remove heavy grease or foreign matter with cleaner, Spec MIL-C-25769, or other material	Normally not required because paint will be removed by mechanical corrosion removal, step 3.	Remove corrosion by abrasive blasting, grinding, wire brushing, and/or sanding
Light or heavy rust on parts as above where chemical rust removal is practical	As Above	As Above	Remove corrosion by wire brushing and/or sanding followed by phosphoric acid etch with Spec MIL-M-10578 material
Light or heavy rust on small parts where vat treatment is practical	Remove grease or foreign matter. Cleaning not required if alkaline corrosion removal method is used	Not required if alkaline corrosion removal method is used or if cleaning is accomplished with paint and varnish remover, Spec MIL-R-7751.	Acid Method. Remove corrosion by immersing parts in phosphoric acid solution, Spec MIL-M-10578 Type III. Alkaline Method. (Recommended for critical or mechanical surfaces). Remove corrosion by immersing parts in alkaline solution, Spec MIL-C-14460 Type I.

53450-2-2-T35

TABLE 36
TYPICAL FINISHING SYSTEMS FOR FERROUS METALS

TYPE SYSTEM	WASH PRIMER	PRIMER	TOP COAT	REMARKS
Alkyd	MIL-C-8514	TT-P-636 or TT-P-664	TT-E-489 (Gloss) or TT-E-529 (Semi-Gloss) or TT-E-527 (lustreless)	Enamel system for general use on ground equipment. Two coats of final top coat are required. Primer TT-P-664 is fast drying.
Vinyl Alkyd	MIL-C-8514	MIL-P-15930	MIL-P-15932 (Gloss Black) MIL-P-15933 (Dull Black) MIL-P-15934 (Gray No. 7) MIL-P-15935 (Gray No. 11) MIL-P-15936 (Gray No. 27)	For use on ground or airborne equipment where temperature does not exceed 200°F. Good moisture and acid resistance. Used in latrine and other areas where increased protection is required.
Inorganic Zinc	None	Purchase Description MONEM-5164	MIL-P-15932 (Gloss Black) MIL-P-15933 (Dull Black) MIL-P-15934 (Gray No. 7) MIL-P-15935 (Gray No. 11) MIL-P-15936 (Gray No. 27)	For use on ground equipment, steel or galvanized steel surfaces subjected to severe environmental conditions, i.e., high humidity, water, weathering or marine environments. May be applied under conditions of high humidity, condensing water or splash. Provides galvanic protection.
High Temperature	None	None	TT-P-28	For use in high temperature areas up to 1200°F. Typical applications are on jet engine tail cones and heat ducts.

53450-2-2-T36

7-61. *Corrosion removal.* You must keep in mind that it is of utmost importance, in removing corrosion from any material, to remove all of it. If corrosion removal is not complete, corrosion often continues after the surface is coated with paint. Mechanical removal is preferred because complete removal is more thoroughly accomplished; however, alkaline or acid corrosion removing solutions may be used to advantage on complex curved surfaces and on parts with deep crevices, threads, or machined surfaces.

7-62. Mechanical removal of corrosion can be done by abrasive blasting, grinding, and wire brushing. Let's explore the methods and procedures.

7-63. Abrasive blasting consists of bombarding a surface with an abrasive at high velocity. The abrasive, usually sand, steel grit, etc., is carried to the surface by air at high velocity. Abrasive blasting is a rapid method for removing corrosion and scale from ferrous metal surfaces. When the abrasive method is to be used, you must protect the adjacent components from scale, chips, corrosion products, chemical agents, and abrasive blast residue. If the material is to be abrasive blasted, the grease or soil present must be removed by one of the cleaning operations we previously discussed.

7-64. Paint may be removed at the same time as corrosion by abrasive blasting with either sand, grit, or shot, as applicable, until the metal surface is free of all scale, corrosion products, slag, and other foreign substances and the metal shows a dull gray-streaked surface.

NOTE: Do not abrasive blast parts where dimensions must be retained, or parts with deep crevices, threads, or machined surfaces. Do not blast metal that is thinner than 0.0625 inch (16 gage U.S. standard).

7-65. After the blasting operation is complete, remove all dust and metal particles by using clean compressed air or a vacuum. After the metal is clean, apply the final protective paint or other corrosion preventive finish recommended in table 36.

7-66. The removal of corrosion by grinding is done with motorized grinding wheels or abrasive belts. Grinding is normally used to remove heavy corrosion by wearing away the corrosion. Part of the base metal is ground away with the corrosion. You should observe these basic steps:

a. Protect the adjacent components from scale, chips, corrosion products, and chemical agents.

b. If grease or soil are present, clean the area by one of the methods previously discussed.

c. Remove paint and corrosion by grinding until a firm rust-free surface is reached. Continue grinding to remove any coarse irregularities. Use a fine abrasive paper to polish the surface to the desired finish.

WARNING: The use of goggles or face shield is mandatory, since corrosion particles break loose and fly.

7-67. Corrosion is removed by wire brushing, which is also an abrasive operation usually done with a hand wire brush or a wire brush mounted on a motor drive wheel. A wide range of abrasive actions is possible by using brushes or various lengths and gages of wire. Wire brushing is used to remove heavy corrosion and imbedded paint or dirt, especially where chemical treatment is not practical. These are typical wire brushing procedures:

a. Protect the adjacent components from scale, chips, corrosion products, and chemical agents.

b. If grease or soil are present, clean the area by the previously discussed methods.

c. Remove any loose corrosion with a hand scraper.

d. Wire brush area to a firm metal subsurface.

e. Remove any remaining rust and condition the metal for painting by applying diluted metal conditioner and rust remover (phosphoric acid base), Specification MIL-M-10578. (Mixing instructions are given later.) Use Type III material to areas only where the material can be thoroughly rinsed from the parts and the adjacent area.

f. Allow the material to remain only long enough to wet and condition the surface. On rusted surfaces, allow the material to remain long enough to loosen the rust.

CAUTION: Use of acids on high-strength steel, heat-treated above Rockwell C40 (180,000 pounds per square inch) tensile strength, is prohibited because of stress corrosion and embrittlement problems.

g. Rinse the surface with water, preferably hot, and permit the metal to dry. Immediately apply protective finish per table 36.

7-68. Chemical corrosion removal is recommended for use where there is no danger that the chemicals will become trapped in crevices or recesses. Chemical rust removers are of the acid and alkaline type. The acid type is intended for removing red rust and black oxide formations by either immersion or brush application of the chemical. The alkali type is intended for removing red rust by immersion treatment. Phosphoric acid type corrosion remover, Specification MIL-M-10578, Type III, is used to remove corrosion from ferrous metal surfaces. The following paragraphs describe both brush-on and immersion type procedures for using the acid.

7-69. Inhibited (Type III) phosphoric acid base rust remover (brush-on method), Specification MIL-M-10578, is used for removing rust and for conditioning the metal surface prior to painting. Type III material should always be rinsed off with water after application.

7-70. Protect adjacent components to prevent damage by scale, chips, corrosion products, or chemicals. Remove any grease or soil by the methods previously discussed. Prior to use of the acid chemicals, remove heavy rust by chipping and/or wire brushing.

7-71. Add one part of the concentrated material as received to one part of water by volume. *Add the acid to the water. Use acid-resisting mixing tanks.*

WARNING: The material contains a strong acid. Protect your hands, face, and eyes. Wear protective clothing. Avoid prolonged breathing of vapors.

7-72. After proper dilutions, apply the material to the corroded area with a brush or swab. Allow the material to remain long enough to loosen the rust (2 to 10 minutes, depending on the degree of rusting).

7-73. Remove the material by rinsing, preferably with hot water. The material must be completely rinsed from the part. If corrosion is still evident, repeat the application and rinsing steps above. Dry the part and immediately apply the protective paint or other corrosion preventive finish listed in table 36.

7-74. Inhibited (Type III) phosphoric acid base rust remover (immersion method for small parts) is used for removing heavy rust from small parts. Corrosion resistant steel tanks are preferred for the immersion treatment. These are the procedures you should use for this type of corrosion removal:

a. Remove grease and loose corrosion as previously mentioned.

b Mix the rust remover, Specification MIL-10578 (Type III), as previously discussed in the brush-on method.

c. Immerse the parts in the solution only long enough to loosen the rust. For removal of heavy rust, heat the solution to 140° Fahrenheit maximum. Agitate the work in the solution to further increase the rate of rust removal.

d. Rinse in a continuously overflowing cold-water rinse tank, if available, or spray with clean, preferably hot, water.

e. Dry the parts and immediately apply the final protective paint or other corrosion preventive finish.

7-75. Alkali type corrosion remover (for removing corrosion from small parts with or without attendant paint, grease, or other surface coating), sodium hydroxide base, Specification MIL-C-14460 (Type I), is suitable for rust removing by simple immersion of the parts. The compound will remove grease, paint, and rust from the parts. This compound may also be used to clean copper and brass and to strip phosphate coatings. Rust can also be removed from critical or machined surfaces with the compound without causing dimensional change of the part.

CAUTION: Do not use alkaline rust remover to remove corrosion from aluminum alloys. Do not process dissimilar metals in the solution.

7-76. Prepare alkaline rust remover, Specification MIL-C-14460 (Type I), in accordance with the manufacturer's instructions as printed on the container. The usual concentration employed for Type I material is 5 pounds per gallon of water. Carbon steel or corrosion resistant steel tanks may be used.

WARNING: Rust remover, Specification MIL-C-14460 (Type I), is highly alkaline, therefore harmful to your skin and eyes. You must wear rubber gloves, aprons, and goggles when working with the material. Use with adequate ventilation.

7-77. Observe these procedures for the use of this rust remover:

a. Immerse parts in the rust remover solution. Rust removal time varies with the extent of the rust. Temperatures up to the boiling point of the solution may be used to increase the rate of rust removal.

b. Rinse thoroughly in clean, preferably hot, water.

c. Dry thoroughly and immediately apply the final protective finish or other corrosion preventive compound as indicated in table 36.

7-78. **Stainless Steel and Nickel-Base Alloys.** Stainless steels are basically alloys of chromium in iron. Other elements such as nickel, sulphur, and molybdenum, columbium, titanium, aluminum, and others may be added to develop special characteristics in the alloy. Stainless steels containing 12 percent chromium or more are resistant to common rusting, chemical action and high temperature oxidation. Corrosion resistance is generally a major factor in the selection of a stainless steel for any application.

7-79. *Cleaning.* Typical corrosion removal and treatment of stainless steel parts and assemblies is outlined in table 37. This table outlines typical procedures for treating stainless steel parts and assemblies. The table provides for corrosion removal by either mechanical or chemical methods and by immersion of small parts.

7-80. As with the metals mentioned earlier, you should clean soiled surfaces of stainless steel before attempting to remove the corrosion from the metal. To clean painted or unpainted stainless steel surfaces where immersion, spray or vapor cleaning is not practical, use alkaline water-base cleaner, Specification MIL-C-25769, or dry cleaning solvent, Federal Specification P-S-661, Type II, prior to attempting paint stripping or corrosion removal. The cleaning procedures used with these materials is the same as mentioned previously with the other metals.

7-81. Where immersion, spray, or vapor cleaning is practical, individual parts may be cleaned by one of the following methods:

- Cleaning by immersion with cleaning compounds, Federal Specification P-C-436.
- Strip paint and clean by immersion in paint and varnish remover, Specification MIL-R-7751.
- Clean by spray-wash with compound, Specification MIL-C-5543, or Federal Specification P-C-437.

TABLE 37
TYPICAL CORROSION REMOVAL AND TREATMENT FOR STAINLESS STEEL

TYPE OF CORROSION	STEP 1 CLEANING TO REMOVE FOREIGN MATTER	STEP 2 PAINT STRIPPING (WHEN APPLICABLE)	STEP 3 CORROSION REMOVAL	STEP 4 PASSIVATION
Light or heavy rust or pitting on installed parts where chemical rust removal is impractical because of the complexity of the structure or rinsing difficulties	Wipe area with solvent, Spec P-S-661, Type II, or Trichloroethylene, Spec, MIL-T-27602	Normally not required.	Remove corrosion with stainless steel wool or wire brush, rotary file, carborundum paper, or other mechanical means	None
As above, except chemical rust removal is practical	Remove foreign matter with cleaner, Spec MIL-C-25769, or other material	Normally not required.	Remove heavy corrosion by brushing, sanding, etc, followed by chemical corrosion removal with Pasa Jell chemical corrosion remover	None
Light or heavy corrosion on parts which can be removed for processing	Remove foreign matter by immersion spray or vapor cleaning	Normally not required. If required, clean and remove paint with paint and varnish remover, Spec MIL-R-7751	Mechanical. Remove corrosion by wire brushing, sanding, grinding, or other mechanical means Chemical. Remove corrosion by pickling in nitric-hydrofluoric acid solution	Passivate in nitric acid solution followed by treatment in sodium dichromate solution

53450-2-2-T37

- Clean by vapor degrease with trichloroethylene, Specification MIL–T–7003 (aircraft parts), or Specification MIL–T–27602 (aircraft or missile parts).

7-82. The procedures for the use of the above compounds are the same as were covered in our previous discussion on cleaning or aluminum.

2-83. *Paint stripping.* Normally, stainless steel parts are not painted. However, if paint is present, it is necessary to remove the paint prior to corrosion removal. This is done mechanically or chemically. The removal method depends upon the accessibility of the area and the degree of corrosion. Mechanical stripping such as sanding with abrasive paper will often remove the paint and the corrosion.

7-84. Paint stripping with chemicals in readily accessible areas may be accomplished with thickened paint stripper, Specification MIL–R–25134. The procedure for the use of this chemical is the same as was discussed for aluminum alloys.

7-85. Paint stripping with chemicals in confined locations may be done by stripping paint with solvents such as ethyl acetate, Federal Specification TT–E–751, or lacquer thinner, Federal Specification TT–T–266. The procedures for use of these chemicals was also covered in the section devoted to the stripping of aluminum alloys.

7-86. *Corrosion removal.* As with the other metals mentioned, the foremost consideration in removing corrosion from stainless steel is that removal must be complete. On stainless steel, the presence of foreign material creates an active-passive corrosion cell between the stainless steel surface (passive area) and the corroded area (active area). It is only when the surface of stainless steel is maintained completely free of corrosion or other foreign matter that the stainless steel can exhibit maximum resistance to corrosion.

7-87. Mechanical removal of corrosion is recommended where chemical removal is impractical because of structural complexities or rinsing difficulties. Mechanical methods include abrasive blasting, grinding, wire brushing (all of which we discussed in the previous area of ferrous metals), or merely abrasing the corroded area with carborundum paper or stainless steel wool until all corrosion is removed. You must use discretion in choosing the corrosion removal method. Obviously, the severe abrasive action of abrasive blasting or grinding cannot be used to remove corrosion from thin wall items such as stainless steel expansion joints in missile propellant systems or missile and aircraft skins.

CAUTION: Use care to protect unaffected areas to prevent additional corrosion damage. Protect materials thinner than 0.0625 inch from severe abrasive action.

7-88. Corrosion may be removed with a stainless steel wire brush, rotary file, stainless steel wool, number 400 carborundum paper, or by abrasive blasting. The following precautions must be observed when applicable to the particular job you are doing:

a. Do not use common steel wool or common steel wire brushes on stainless steel. Wire particles may become imbedded in the surface and may later corrode. Use only stainless steel wool or stainless steel wire brushes.

b. Use abrasive blasting on heavily corroded parts as an operation preliminary to acid pickling. Nonmetallic abrasives such as clean silica sand or glass beads are used in order to prevent contamination of the stainless steel surface with imbedded particles of iron.

c. After all corrosion has been removed thoroughly, flush the treated area with clear water. Wipe dry with a clean, lint-free cloth. Drying may be facilitated by swabbing the area with a clean cloth saturated with isopropyl or denatured alcohol.

d. After removing all corrosion visible with a four-power magnifying glass, remove an additional amount of material to a further depth of at least 0.002 inch to insure that no corrosion products remain.

e. The cleaned area must be blended into the surrounding area so that a saucer-shaped depression is formed to eliminate stress concentration.

f. After completing mechanical removal, polish the area first with number 400, then with number 500 emery cloth. If a finer finish is desired, use number 600 emery cloth.

g. Apply the final protective finish if required.

7-89. Chemical removal of corrosion is recommended for severely corroded areas where chemicals are not likely to become entrapped in recesses or structural complexities or where there is some possibility of damaging the surrounding metals and plating by using other methods. Use the following chemical procedures on installed components not readily removable:

a. Protect the adjacent unaffected areas not being treated to prevent additional corrosive attack. When internal corrosion is evident, the components should be removed and processed through an overhaul facility in accordance with the specific directives dealing with that situation.

b. Protect the nearby noncorrosive-resistant steel alloys, plated areas, copper-bronze alloys, aluminum alloys, braided flexible lines, and operating mechanisms to prevent the chemical treating solution from coming in contact with those areas.

c. Remove all loose corrosion by brushing with a stainless steel wool or number 400 carborundum paper.

d. Remove all loose particles by wiping with a clean cloth dampened with methylene chloride or trichloroethylene.

WARNING: In areas of oxygen storage and transfer systems use only trichloroethylene. Specification MIL-T-27602. Apply only to immedidiate corroded area. Do not allow solvents to splash or run, because they also remove paint and damage elastomers.

CAUTION: In order to prevent additional damage from corrosion. protect surrounding unaffected areas next to the area being treated by preventing leakage of chemicals into recesses or inaccessible areas.

e. In areas of oxygen storage and transfer systems, remove the remaining corrosion by applying a liquid oxygen compatible corrosion remover (Pasa-Jell Nr. 101, stainless steel type) with an acid-resistant brush. For removal of light to medium corrosion, apply Pasa-Jell to affected area, agitating with an acid-resistant brush if necessary. For heavy corrosion where pitting is present, agitate Pasa-Jell on the surface with abrasive mat, Specification MIL-A-9962, Type II, until all corrosion embedded in pits and on the surface is removed.

WARNING: Do not use aluminum or steel wool to agitate Pasa-Jell. A combustible reaction occurs. Pasa-Jell contains strong acids. Observe standard safety precautions for handling acids. Wear protective clothing. Avoid breathing fumes and provide adequate ventilation.

f. Remove Pasa-Jell solution and corrosion products with a clean lint-free cloth frequently rinsed in clear water. For final wipe, use clean, lint-free dry cloth.

g. In areas where there is no danger of liquid oxygen spillage, corrosion may be removed with phosphoric acid base rust remover, Specification MIL-M-10578, Type III, using the procedures outlined in the area covering ferrous metals.

h. Thoroughly rinse all chemical corrosion remover from the area.

i. Allow the area to dry, then apply the final protective finish or other corrosion preventive if required.

CAUTION: The heat-treatable straight-chromium alloys such as AISI Types 403, 410, 420, and others, are susceptible to cracking when placed in pickling solutions. Corrosion removal by brushing, grinding, etc., is therefore recommended.

7-90. Mixtures of nitric and hydrofluoric acid in water are recommended for pickling solutions for stainless steel. The correct percentage content of the two acids for a given corrosion removal job is determined by testing (see the portion of this text dealing with pickling solution on titanium). The nitric acid content may vary from 5 percent to 50 percent and the hydrofluoric acid from 0.5 percent to 5 percent, both by volume. Normally, 12 to 15 percent nitric acid and 1 percent hydrofluoric acid is used to remove light scale or corrosion. The percentage of hydrofluoric acid may be increased to remove heavier scale or corrosion. The more nitric acid present with respect to hydrofluoric acid, the less rapid the corrosion or scale removal. Nitric acid acts to inhibit the action of the hydrofluoric acid. Rubber-lined or Koroseal tanks may be used to hold the solutions. (Refer to table 34.)

7-91. Pickling temperatures are adjusted from room temperature to 140° Fahrenheit. Higher temperatures must be avoided to reduce evaporation loss of hydrofluoric acid. Temperatures below 120° Fahrenheit are used if intergranular attack is experienced in localized areas such as weld zones of the metal. For complete information on the pickling process of stainless steel, consult Technical Order 1-1-2.

7-92. *Painting*. Stainless steels are normally not painted. However, where extreme corrosive conditions are encountered, or where organic finishes are required for decorative purposes, finishing systems as outlined in table 32 are used.

7-93. **Magnesium.** Magnesium alloys are the lightest structural metals used extensively throughout aircraft and missile airframes. These alloys are highly susceptible to corrosion when the metal surface is exposed to the environment without a protective finish. The normal oxide-carbonate film formed on magnesium does not provide sufficient protection for the metal to prevent further corrosion, as the oxide film does with aluminum and titanium. The rate of corrosion formation on magnesium increases when the metal is immersed in water or periodically subjected to moisture. Corrosion may also be accelerated by dissimilar metal couples and when conductive contamination is dissolved in the water. Corrosion can be overcome or greatly diminished by the use of the proper protective finish.

7-94. Table 38 outlines typical procedures for cleaning and treating magnesium and magnesium alloy parts and assemblies of aircraft and missiles.

TABLE 38

TYPICAL CORROSION REMOVAL AND TREATMENT PROCEDURES FOR MAGNESIUM ALLOYS

TYPE OF CORROSION	STEP 1 CLEANING	STEP 2 PAINT REMOVAL	STEP 3 CORROSION REMOVAL	STEP 4 SURFACE TREATMENT	STEP 5 PROTECTIVE FINISH
Light pitting or surface oxidation.	Remove foreing matter with cleaner, MIL-C-25769 or P-D-680 Type II.	Readily accessible areas: MIL-R-25134. Confined areas, Paint Thinner.	Remove corrosion with chromic acid pickle solution.	One of the pretreatment processes described herein.	Approved Paint system.
Heavy Pitting or etching.	As above.	As above.	Remove corrosion by mechanical and chemical methods.	As above.	As above.
Intergranular or exfoliation.	As above.	As above.	Remove corrosion by mechanical method.	As above.	As above.
Stress.	Not Applicable. Repair/Replace as required in structural handbook.	Not applicable.	Not Applicable.	Not Applicable.	Not applicable.

53450-2-2-T38

The table provides for corrosion removal by either mechanical or chemical methods. Several types of treatment are approved for magnesium and magnesium alloys; however, for the purposes of this text only one brush-on treatment is outlined. Parts which can be removed may be treated more completely with electrochemical (galvanic anodizing) conversion coating by methods outlined in Technical Order 42C2-1-7.

7-95. *Cleaning.* As with the other metals we have discussed, if the corroded area of magnesium or magnesium alloy is soiled by grease, dirt, or other foreign materials, it is necessary to clean the area prior to any paint stripping or corrosion removal.

7-96. If it is not practical to clean painted or unpainted magnesium or magnesium alloy surfaces by immersion, spray, or vapor cleaning, they are cleaned with alkaline water-base cleaner, Specification MIL-C-25769 or Federal Specification P-D-680, Type II. Instructions for use of MIL-C-25769 have been previously discussed in the preceding paragraphs. P-D-680 may be wiped on or sprayed if conditions permit. Normal precautions for use of aliphatic flammable solvents must be observed.

7-97. Where cleaning of individual parts by immersion, spray, or vapor cleaning is practical, refer to technical order 42C2-1-7 for complete instructions and procedures.

7-98. Magnesium may be paint stripped in the same manner as aluminum and aluminum alloys.

7-99. *Corrosion removal.* Corrosion may be removed from magnesium and magnesium alloys just as it is from aluminum. Also, the removal must be complete, as we want to avoid any further corroding after the affected area has been refinished.

7-100. By chemical means, corrosion is removed by the previously described chromic acid pickle solution. This is used to remove surface oxidation and light corrosion from magnesium surfaces. It is not considered adequate if deep pitting or heavy corrosion has occurred—which require mechanical methods—nor is it satisfactory for removing sand or the effects of blasting. The chemical method causes less reduction in section thickness if properly used. This method is not used for parts containing copper-based inserts unless the inserts are masked off. Excessive amounts of anions, such as chlorides, sulfates, and florides, must not be allowed to build up in the solution, as these anions instead of cleaning the surface, tend to coat or etch the metal.

WARNING: *Add the chromium trioxide to the water. Do not add water to the chromium trioxide.*

7-101. In the use of chromic acid solution for removal of corrosion on magnesium, prepare and use the chromic solution as follows:

Chromium Trioxide (O-C-303, Type II)	24 oz.
Water to make solution	1 gal.
Reaction time	1 to 15 min.
Solution temperature	190° to 202° F.
Container construction	Lead lined steel or stainless steel or 110 aluminum

Note: Solution can be operated at room temperature for a longer reaction time if desired.

a. Mask off any nearby operating mechanisms, cracks, and plated steel to keep the solution from attacking them.

b. Apply the chromic acid solution carefully to the corroded area with an acid-resistant brush.

c. Allow the solution to remain on the surface for approximately 15 minutes. Agitation may be required.

d. Thoroughly rinse the solution from the surface with clean clear water.

e. Repeat the preceding sequence as necessary until all corrosion has been removed and the metal is bright and of a metallic color.

f. Apply the chemical pretreatment and final protective finish recommended for the area.

7-102. *Pretreatment.* Chemical pretreatment such as chromic acid brush-on solution provides a passive surface layer with an inhibitive characteristic that resists corrosive attack and also provides a bond for subsequent coatings. Properly applied magnesium pretreatments tend to neutralize corrosion media in contact with the surface. Numerous treatments are available; however, for our purposes, we will discuss only the following brush-on treatment corresponding to Type VI of MIL-M-3171.

7-103. The chromic acid brush-on pretreatment may be applied to all magnesium parts that require touchup. This treatment is generally used in refinishing procedures or when parts and assemblies are too large to be immersed. This treatment is less critical to apply than the other brush-on treatments, is relatively inexpensive, not as harmful when trapped in faying surfaces, and does not present the toxicity hazards of the other brush-on treatments. Insure that all contaminates, grease, oil, etc., are removed prior to the treatment process.

WARNING: *Add the chemicals to the water* in the order shown, stirring the solution vigorously either mechanically or by air agitation for at least 15 minutes. Avoid contact with your skin or inhalation of the acid fumes.

Chromic acid brush-on solution:		
Chromic acid (CrO_3) (99.5% pure)	1⅓	oz.
Calcium sulphate ($CaSo_4 \cdot 2H_2O$)	1	oz.
Water to make	1	gal.
Operating temperature	70–90° F.	
Container material	Stainless steel, aluminum, vinyl polethylene, or rubber.	

a. Proper application requires that the surface be kept wet with the brush-on solution for a sufficient time to produce the desired film. This time is usually 1 to 3 minutes; however, the treatment time must not be less than 30 seconds nor longer than 3 minutes. Up to 1 minute produces a brassy film, and 2 to 3 minutes a dark brown coating. Prolonged treatment produces loose powdery coatings which must be removed prior to applying further protective coatings. For best paint adhesion the dark brown coatings are preferred.

b. Apply pretreatment coating, Specification MIL-C-8514, to the treated surface as soon as practical after thorough drying.

c. Apply the recommended final protective finish.

7-104. *Painting.* Use the paint systems that are recommended for aluminum (see table 32). The use of the chromic acid pretreatment coating is essential for increasing the corrosion resistance of paint systems on magnesium. Wash primer, MIL-C-8514, applied over bare magnesium, attacks the magnesium, causing poor paint adhesion and corrosion of the magnesium. Touchup of broken conversion films on magnesium must be treated as previously described in the chromic acid brush-on pretreatment prior to application of any paint system.

7-105. **Typical Aircraft Repair Protection.** In this section we have discussed corrosion prevention from the identification, removal, and prevention approach. That is, when corrosion is previously evident, we must know how to remove and prevent corrosion; but more importantly, we must also know how to prevent corrosion from getting started as a result of our own repair and fabrication of aircraft parts. We have been told time and time again, "Don't scratch the metal," but we know from experience that no matter how careful we are, the metal does get scratched, unfortunately. What do we do after the metal is scratched—throw it away? Hardly. We must economically use the metal, and by proper treatment, it can be used.

7-106. During fabrication there are several basic procedures that must be adhered to. Later in this course, specific repairs and repair procedures will be covered. For now, let us deal with the intermediate steps of applying primers and paint finishes where needed.

7-107. In the previous chapter we discussed the identification of metal as to its metallic content. When approaching any fabrication repair this must be the first thing determined.

7-108. Before the metal surface to be patched is cut out, use a zinc chromate primer, either spray or brush-on type, as a cover to mark the cutout. (This primer, as you know, is readily available.) This insures that any errors about to be made can be corrected prior to the actual cutting of the metal.

7-109. After the cutout is completed and trimmed and all residue of the damage is removed, all surfaces that will come in contact with the repair material must be primed as an added element of corrosion resistance to insure that when assembly is completed the inner parts of the repair material faying surfaces have been protected.

7-110. After drilling holes in the parts to be assembled, they should be zinc chromated on the inner and the outer surfaces to insure that all contacting surfaces—metal, rivets, bolts, washers, etc.—have the corrosion protection needed.

7-111. Painting surfaces of an aircraft is not normally the responsibility of the airframe repairman, but in many cases areas of repair and fabrication must be spot-painted to lessen the potential of corrosion, especially in the environmental areas mentioned in the section on causes of corrosion.

7-112. Aircraft finishes range in types from lacquer or enamel to epoxy, which may be applied either by spraying or brushing. When it is necessary for you to place a finish on the repair you have completed, consult table 32 for aluminum alloys, table 36 for ferrous metals other than stainless steel, and table 38 for magnesium alloys. Be sure to comply with Technical Order 1-1-8, *Application of Organic Coatings*.

7-113. Now turn to the workbook and answer exercises for Section 7.

Metal Cutting

"HAND ME THAT nibbler." How many people outside the airframe repairman career field would know what tool was needed by the person making that request? When working with the tools of your trade, knowing the names of the different tools, proper selection for a particular job, and maintenance of the tools are as much a part of the trade as using the tools themselves.

2. In the preceding chapters we discussed common materials used to fabricate pieces and parts for aircraft, the advantages and disadvantages of the materials, and their characteristics. In this and the following chapter we discuss tools (shop and kit) which you use to transform metal into usable parts for aircraft. We include the selection and maintenance of metal cutting, nibbling, drilling, punching, and abrasive tools.

3. Upon completion of this chapter you should be able to select and identify proper tools, and to explain and describe the use and maintenance of tools and equipment you work with.

8. Metal Shearing Tools

8-1. Shearing tools used in the airframe repair shops are of great value to individual workers, and a variety of shearing tools and equipment is available for your use. Remember when using shearing tools, that each has specified uses and limitations as to what materials it can be expected to shear under certain conditions. If the metal is too thick or hard, either the tool or the material can be damaged. Always, prior to using any machine, check the manufacturer's data plate for capacity, and read the operating instructions and safety precautions.

8-2. **Utility Lever Shears.** Utility lever shears, shown in figure 18, are used for general work around an airframe repair shop and are especially useful for cutout work such as angles of specific degrees. The lower blade is attached to the table, making it possible to cut to the line with accuracy. The scribed line is always visible to the machine operator, permitting outside, straight, and irregular cuts. The upper blade moves up and down by means of a counterbalanced hand lever. In most cases, utility lever shears are equipped with an angle gage, miter gage, and depth gage. These gages assist in cutting duplicate pieces of metal to desired size and shape without repeated layout marking and machine adjustment.

8-3. The cutting blades of the utility lever shears vary in size from 6 to 9 inches and have a throat in the frame ranging from 9 to 20 inches. This machine is limited to cutting mild steel of 10 gage or less. Make sure that the gage of the material to be cut is within the capacity of the particular machine you use.

8-4. When operating utility lever shears, be careful to keep your fingers away from the cutting blades. During cutting operations, always return the counterbalanced hand lever to the full up position to prevent it from accidentally lowering the upper cutting blade.

8-5. **Scroll Shears.** Scroll shears are used for cutting irregular lines on the inside of a sheet without cutting through to the edge. Note in figure 19 that the upper cutting blade is stationary while the lower blade moves. The handle for operation is attached to the lower blade. Scroll shears, like lever shears, have a guide to regulate the length of cut.

8-6. Observe ordinary safety precautions such as keeping your fingers away from the cutting blades; do not exceed the recommended material thickness while cutting.

8-7. **Throatless Shears.** These shears, illustrated in figure 20, get their name from their construction because the frame is throatless and a sheet of any length may be cut. The metal can be turned on any direction to allow for cutting irregular shapes. Radius cuts in heavier gage metal can be made easily with throatless shears. The cutting blade (top blade) is operated by a hand lever. Be sure to keep your fingers away from the cutting blades, to return the handle to full up position after the cutting operations, and

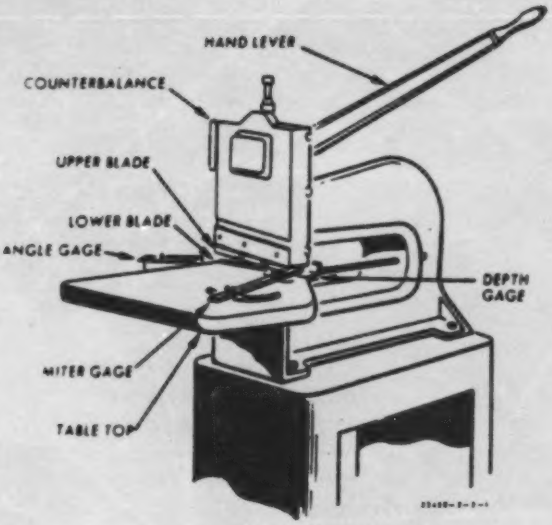

HAND LEVER
COUNTERBALANCE
UPPER BLADE
LOWER BLADE
ANGLE GAGE
DEPTH GAGE
MITER GAGE
TABLE TOP

Figure 18. Utility lever shears.

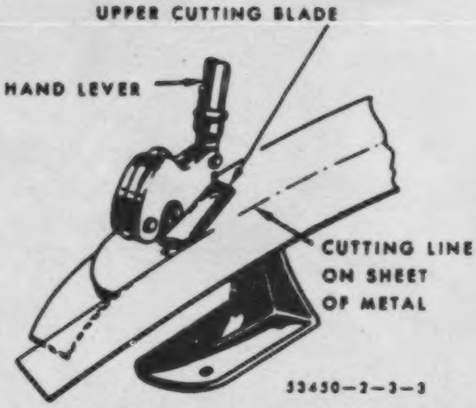

UPPER CUTTING BLADE
HAND LEVER
CUTTING LINE ON SHEET OF METAL
53450—2—3—3

Figure 20. Throatless shears.

to protect your fingers and hands from burrs when guiding metal through the cutting blades.

8-8. The lower (fixed) blade should be kept in proper adjustment and inspected prior to use. If the blades are too close, they lose their sharpness and may be damaged. If the blade gap is too wide, the metal has a tendency to fold, causing a bad cut. The lower blade is adjusted with setscrews.

8-9. **Circle Shears.** Circle shears, illustrated in figure 21, are used to greatest advantage when cutting circular blanks for cylindrical objects. These shears can also be used for slitting sheets and are equipped with a guide for that purpose. They are best suited for cutting discs from mild steel, copper, and aluminum.

8-10. *The principal parts* of the circle shears are the bed, yoke, and rotary cutters. The bed, since it must absorb and withstand the majority of the load and shock, is made of strong steel plate. On the top of this bed is a scale, with graduations to one-sixteenth of an inch, to indicate the approximate diameter of the circle you are cutting. The yoke, or sliding circle arm, centers and holds the sheet. The position of the yoke is governed by the diameter of the cut. To adjust the yoke, loosen the locknut (usually located at the base of the yoke) and slide it along the bed. Attached to the yoke is the clamping device which is operated by a clamping handle. Setscrews and locking nuts are used to adjust the pressure on these clamping devices. A hardened center pin, in the lower disc, aids you in centering blanks of center punched metal.

8-11. *The upper rotary cutter* on this machine can be adjusted in a vertical position and should overlap enough to cut through the metal in one cut. The adjusting screw is usually located directly above the upper cutter. The bottom cutter can be adjusted in the same manner but in a lateral direction. For light gage metal, the cutters should just touch and operate freely. When

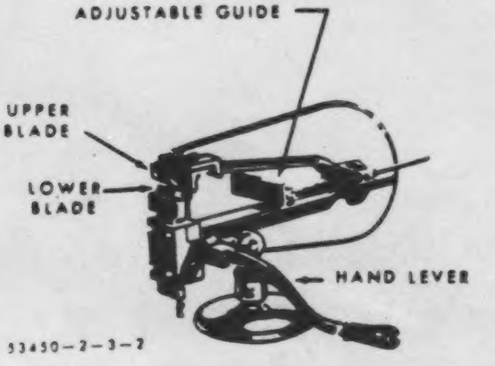

ADJUSTABLE GUIDE
UPPER BLADE
LOWER BLADE
HAND LEVER
53450—2—3—2

Figure 19. Scroll shears.

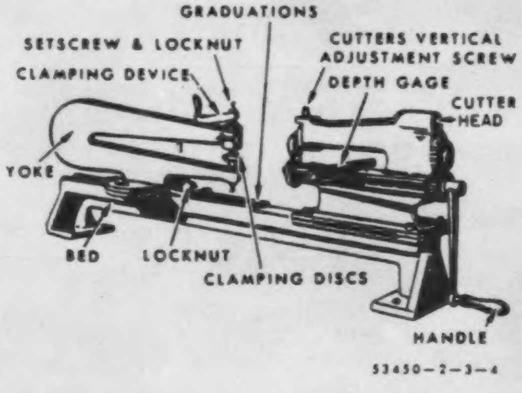

GRADUATIONS
SETSCREW & LOCKNUT
CUTTERS VERTICAL ADJUSTMENT SCREW
CLAMPING DEVICE
DEPTH GAGE
CUTTER HEAD
YOKE
BED
LOCKNUT
CLAMPING DISCS
HANDLE
53450—2—3—4

Figure 21. Circle shears.

cutting heavy material, the cutters should be separated slightly, but this opening should be limited to a maximum of 10 percent of the metal thickness.

8-12. When you are cutting circular blanks with circle shears, first cut the metal to approximate size. Place the blank between the clamping discs and adjust the yoke so that the distance from the center of the clamping discs to the cutting wheels is one-half the diameter of the blank desired. Then adjust the upper cutting blade with the vertical adjustment screw. You should stand at the side of the shears with the cutting head to your left when operating the machine with the handle so that the metal feeds away from you. Do not attempt to cut inside circles with this machine. Always start the cut from the edge of the sheet.

8-13. Safety precautions, when using circle shears, again include keeping your fingers from the cutters, gears, and burrs. When working with this machine (or any other gear-driven machine), make sure your clothing is not loose enough to become engaged in the gears.

8-14. **Manually Operated Squaring Shears.** These shears are similar to power-operated squaring shears which will be discussed later. The foot supplies the action and power required to operate the cutting blade. The back gage and holddown handles are also manually operated. Although many types of foot-operated shears are manufactured, basically they are all similar. If you can operate one successfully, you should be able to operate the others.

8-15. The shears illustrated in figure 22 have two large springs, one at each end of the housing, which raise the blade when pressure is removed from the treadle. A graduated scale is scribed on the bed as a guide for cutting correct lengths. At each end of the bed, there is a side gage which aids in keeping the metal square with the blades. After the first cut is made and it is found that the cut is not square, the error can be corrected by loosening the locking bolts and readjusting the side gage. If it is necessary to cut long sheets of metal that must be pushed from the back side, the two extension arms can be used in conjunction with the front gage. The metal gage limit of this particular shearing machine is usually 16-gage mild carbon steel. If the metal is heavier, use power shears.

8-16. The holddown attachment on foot-operated shears can be either spring actuated or manually controlled. These holddowns, if adjusted properly, have an advantage over hand-holding, which usually allows the material to slip, causing inaccurate cuts. On very light or short cuts, accuracy of cut can be maintained on material held by hand.

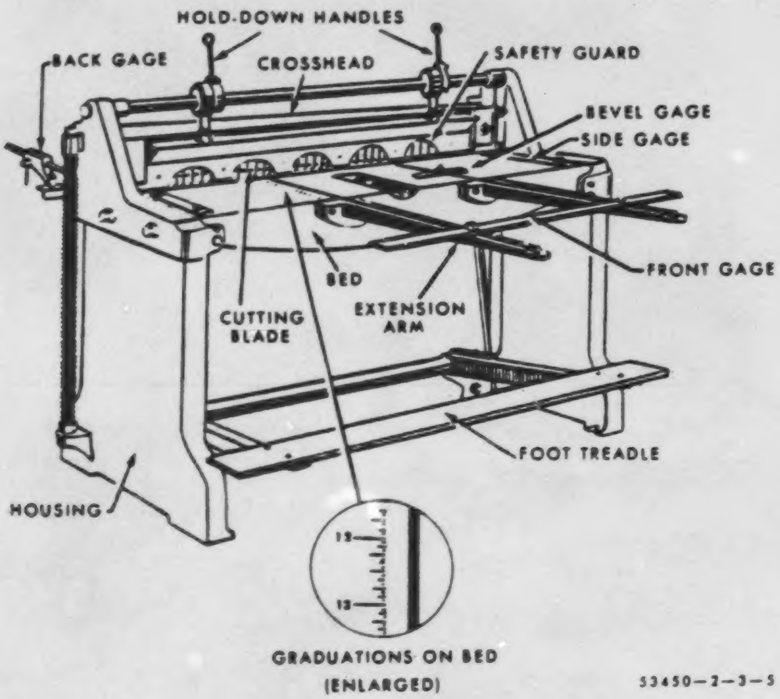


Figure 22. Manually operated squaring shears.

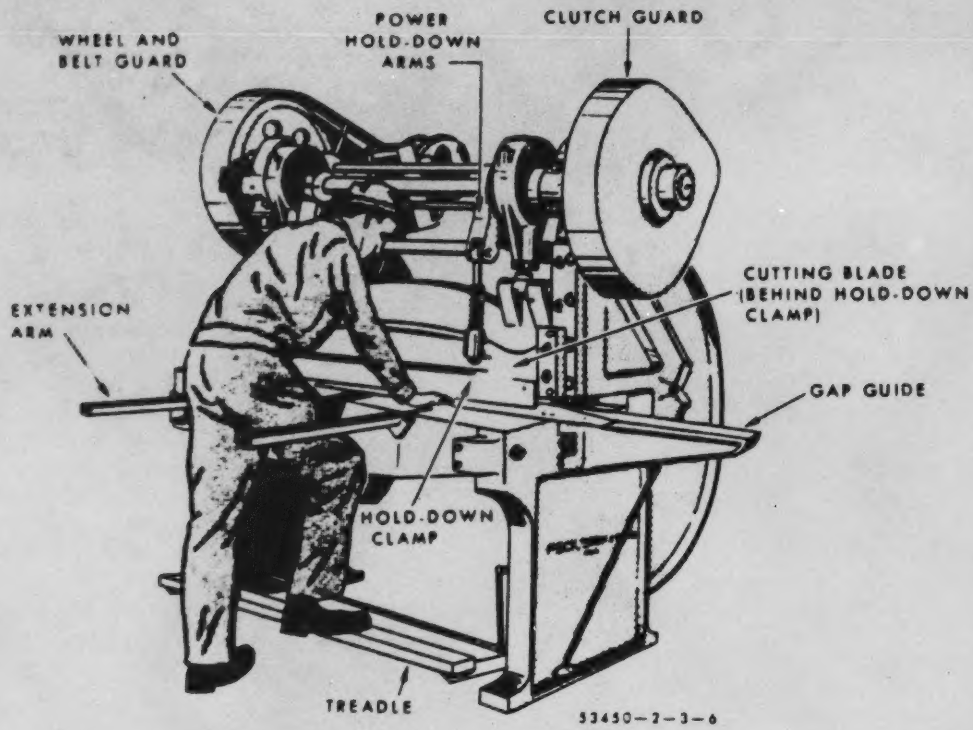


Figure 23. Power-operated squaring shears.

8-17. The squaring shears are used for many necessary operations and save a great deal of work when cutting to a line, squaring, and when multiple cutting to a specific size. For cutting to a line, place the sheet on the bed of the shears in front of the cutting blade, with the cutting line even with the cutting edge of the bed. Pull the holddown handles forward to lock the metal in place. Then cut the material by stepping on the treadle which completes the cutting cycle.

8-18. Squaring a piece of metal requires several steps, the first of which is the trimming of one edge. Do this by inserting the metal between the blades of the shears and by cutting off approximately one-quarter of an inch of metal. Square the remaining edges by holding a trimmed edge against the side gage and by making the remaining cuts one edge at a time.

8-19. For cutting several pieces of metal to the same dimensions, use the back gage (production gage). This gaging device, shown in figure 20, consists of two support rods, graduated in fractions of an inch, and a square fence that can be set at any point on the support rods. To use the gage, set the squaring fence at the desired distance from the cutting blade by loosening the locking knobs and turning the adjusting knobs. After all adjustments have been made, lock the fence in position and insert the metal between the blades of the shears until the edge of the metal comes in contact with the squaring fence. To insure accuracy of cut, be sure that the edge of the metal is flush all along the fence. Then pull the holddown handles to clamp the metal. The successful use of this gage depends upon a few predetermined adjustments; once the gage adjustments are made, many pieces of metal can be cut to the same dimension without additional measuring.

8-20. Safety precautions to be observed when using manually operated squaring shears are practically the same as those for power-operated squaring shears. However, when pushing down on the foot treadle, which requires considerable force, be sure your other foot is clear of the foot treadle.

8-21. **Power-Operated Squaring Shears.** Squaring shears, illustrated in figure 23, provide a convenient means of cutting and squaring sheet metal stock. Learn how to use this tool properly because it will, among other things, increase production.

8-22. This machine consists of a lower blade, stationary on the bed of the shear, an upper blade attached to a crosshead, and a holddown clamp to hold the metal securely during cutting. The holddown clamp allows the operator to get his hands out of the way during the cutting operation.

The table of the power shears has extension arms, similar to the manually operated shear, which provide support for long sheets of metal. Extending to the right of these arms, but still on the bed, is a guide graduated in sixteenths of an inch. This guide can be used as a measuring scale for cutting short lengths of metal. It also keeps the metal square with the blade when adjusted correctly. The guide is not shown in figure 23, since the machine as illustrated is set up to cut long sheets of metal. However, it is similar to the side gage of the manually operated squaring shears, shown in figure 22. Control switches are provided for operating the power shears. The back gage is adjustable and can be moved forward or backward, depending on the length of cut required. There is no need to measure between the back gage and the fixed horizontal blade because all measurements can be read on the back gage, graduated in sixty-fourths of an inch. By depressing the treadle, you engage an automatic clutch which sets the shearing blade in action. The shears will go through only one cycle of action each time the treadle is depressed and released. If continuous operations are desired, simply continue to hold the treadle in the down position. Once the treadle is released, the machine stops when it completes the cycle of operation. Be sure to turn off the shears after all cuts are made and to remove the material that has just been cut.

8-23. Before operating power shears, you should check the machine to see that it is clear of material and personnel. For instance, someone might be making repairs behind the machine. If power to the machine is turned off, there is usually a reason; therefore, check with your supervisor for the cause. In some shops a "Caution Repair" tag is used to identify the status of the machine. If there is such a tag on the machine, do not attempt to remove the tag. The person making repairs will remove it when the work has been completed. The machines you use are equipped with guards for your protection, and the guards should never be removed except when the machine is disconnected from its power source for repairs. The blade guard is not visible in figure 23, because it is located between the holddown dogs and cutting blade. The blade guard, similar to the safety guard shown in figure 22, is designed to keep your hands and fingers away from the cutting blades during operation. Wheel and belt guards are provided to protect personnel and to keep foreign objects from being caught in the moving parts. When making cuts, always make certain that the cutting blades are clear before releasing the clutch to actuate the holddown dogs and the blade. Make sure that your fingers are clear of the holddown dogs when they

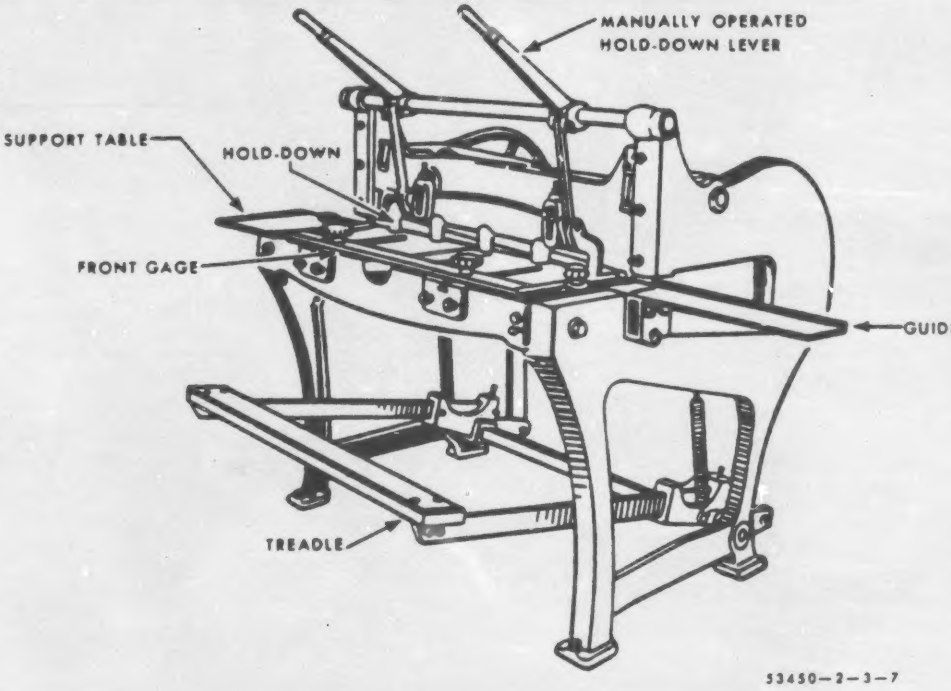


Figure 24. Gap squaring shears.

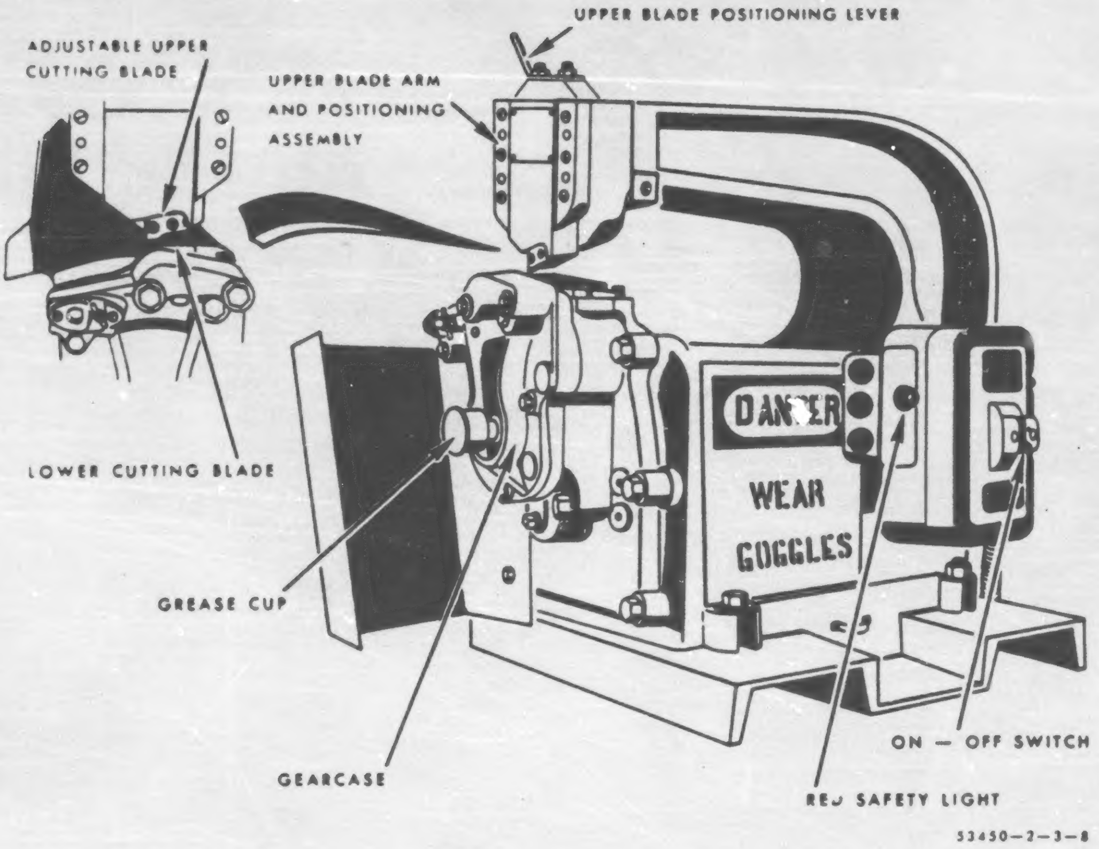

UPPER BLADE POSITIONING LEVER
ADJUSTABLE UPPER CUTTING BLADE
UPPER BLADE ARM AND POSITIONING ASSEMBLY
DANGER
WEAR
GOGGLES
LOWER CUTTING BLADE
GREASE CUP
ON — OFF SWITCH
GEARCASE
RED SAFETY LIGHT
53450—2—3—8

Figure 25. Stationary unishears.

are actuated, because to keep your metal in place during shearing, tremendous pressure is applied. These dogs have been responsible for the loss of as many fingers as has the shearing blade.

8-24. **Gap Squaring Shears.** The gap squaring shears, illustrated in figure 24, resemble manually operated squaring shears except that the frame is built to accommodate any width or length of sheet metal stock for slitting. The front opening or gap is usually about 18 inches deep for shears with a capacity of 16-gage mild steel. These shears have a supporting table on the left side to keep the sheet level with the surface of the bed; on the right side is another guide used in slitting long sheets of metal. Constructed as they are, these shears can be used to cut one piece or several pieces from a sheet of metal longer than the machine. This type of work is done by first adjusting the front gage to the desired width, making sure that the gap is deep enough to allow easy passage of the metal. The metal is moved between the cutting blades from left to right, and a cut is made about three-quarters the length of the blade. Then the holddown levers are released and the sheet moved to the right so that the edge of the metal will ride against the guide. This is repeated until the cut is completed.

8-25. Safety precautions when operating gap squaring shears are similar to those precautions for manually operated squaring shears.

8-26. **Unishears.** You will find unishears useful equipment in the airframe repair shop. Figures 25 and 26 illustrate two types, stationary and portable. Both are designed to cut along irregular lines on sheet stock and will save you much time, since they cut faster than hand snips or shears.

8-27. The stationary unishears, illustrated in figure 25, are powered by an electric motor which moves the lower cutting blade up and down to cut the sheet stock as it is guided through the blades. It is possible to make straight or irregular cuts through sheet stock as heavy as 16 gage. The upper cutting blade does not reciprocate during cutting; however, the upper blade positioning assembly can be raised with the upper blade positioning lever when it is necessary to open the throat of the shears to make inside cuts. The blade is lowered before the machine is operated. The cutting blades are adjusted for clearance when new blades are installed; therefore, they do not need readjustment for different gages of metal stock. A red safety light, located near the ON-OFF switch, is illuminated when the motor is operating. The grease cup located in the gearcase is packed with gear lubricant and must be tightened by hand to lubricate the moving parts.

8-28. In figure 26, you can see how irregular cuts in sheet stock are made with electrically driven portable unishears. Notice how the shears are guided through the metal. This is rather easy to do, because the shears are throatless and can be turned to the right or left without releasing the forward pressure. Portable unishears are held in either your right or left hand and are used in the shop if electrical power is available.

CAUTION: Electrically driven power tools are never used on aircraft, because of the danger of explosion due to sparks created by the electric motors.

8-29. Accuracy when cutting with either the stationary or portable unishears is determined by the operator; therefore, it is important to align the upper cutting blade with the line being cut in the metal. If you look a few inches ahead of the cutting blades, you should get better results. Apply just enough pressure to insure that the

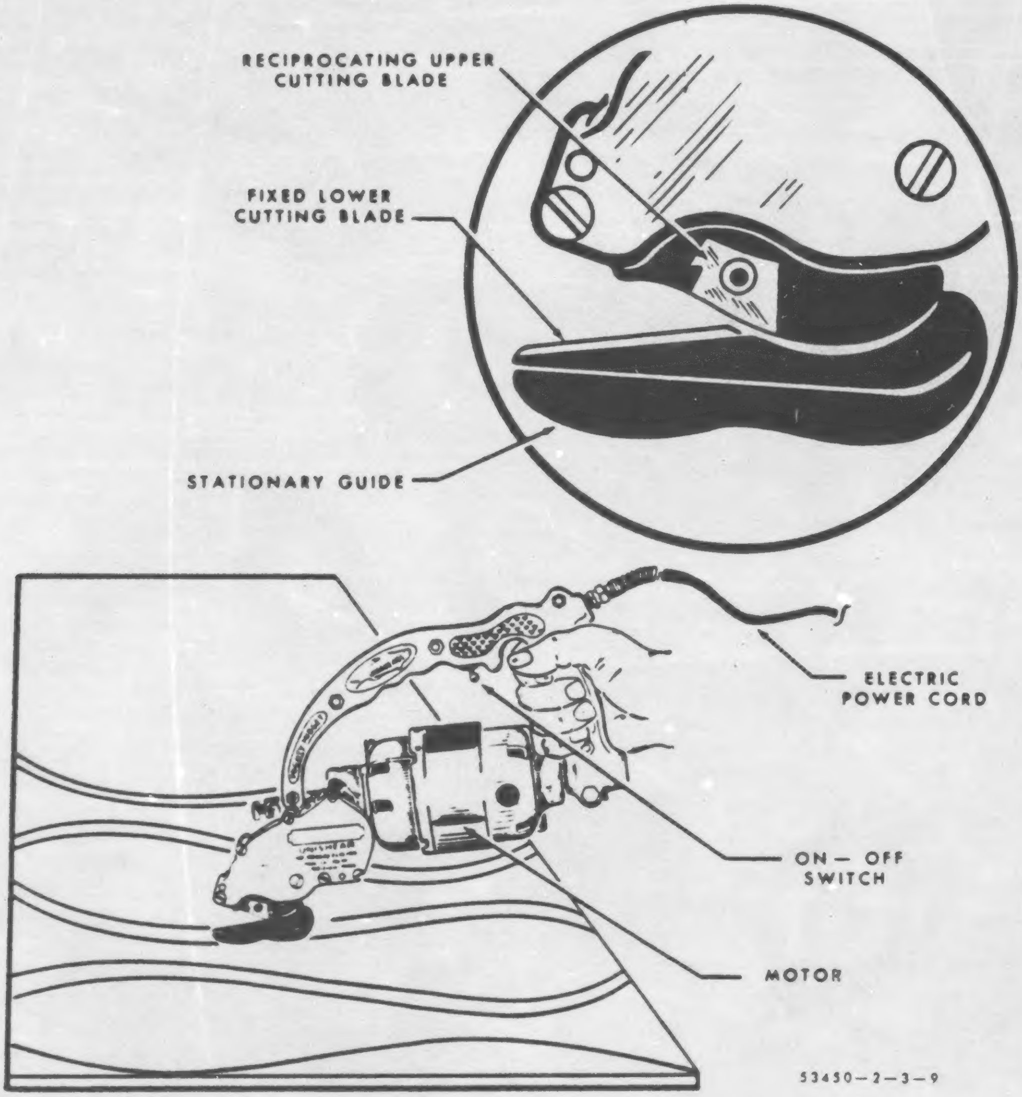


Figure 26. Portable unishears.

blades are cutting smoothly at all times. Too much pressure will overload the machines, and too little pressure will cause the metal or machine to jump from side to side, resulting in very sharp burrs.

8-30. Observe these safety precautions when using either of these unishears. Keep your hands and fingers clear of the cutting blades at all times, and avoid the burrs. Keep the power cord of the portable unishears clear of the burred edges to prevent damage to the insulation of the cord. Check the three-prong connector on the power cord before connecting it to a properly grounded power receptacle.

8-31. Before we continue to Section 9, turn to the workbook and answer the exercises for this section.

9. Metal Cutting Tools

9-1. Many times you may find it impractical to use metal shearing tools because of the type or location of the work you are doing. In such cases, it is necessary for you to use metal cutting tools instead. Among the most frequently used cutting tools are various types of hand snips, chisels, hack saws (both hand and powered), band saws, ketts saws, hole saws, and reciprocating saws.

9-2. **Aviation Snips.** The aviation snips, illustrated in figure 27, are available to you in left- or right-hand cut. Two pairs of snips are required—one for cutting to the left and one for cutting to the right. This does not mean that they are made for left- and right-handed people as in the case of the straight snip, which we will discuss later.

9-3. Aviation snips are designed especially for cutting heat-treated aluminum alloy and stainless steel. They are very adaptable for enlarging small holes. The blades have small teeth on the cutting edges and are shaped for cutting very small circles and irregular outlines. The handles are of the compound leverage type which makes it possible to cut material as thick as 0.051 inch. You will find these snips very useful for cutting any shape of holes in panels and for similar jobs.

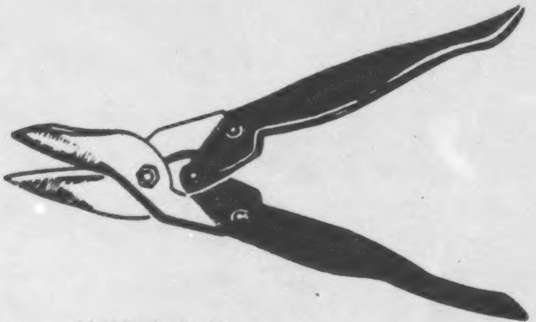

53450-2-3-10

Figure 27. Aviation snips.

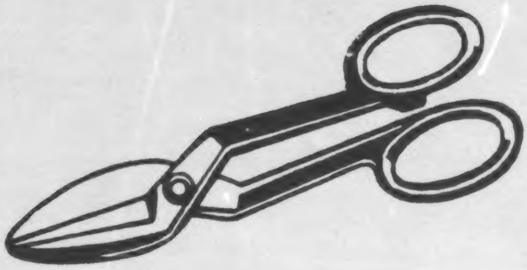

53450-2-3-11

Figure 28. Straight snips.

9-4. **Straight Snips.** Straight snips are designed to cut straight or long curved lines in sheet stock. The straight snips shown in figure 28 are available (one pair) for right-handed people and (one pair) for left-handed people.

9-5. Never use straight snips as pliers or wire cutters, or on heavier material than that for which they are intended. Such improper usage may spring the blades and make the snips useless. When cutting, place the upper blade of the snips on the line to be followed and keep the blade perpendicular to the surface of the metal. The waste metal (or the smaller piece) should curl up along the upper edge of the lower blade.

9-6. **Chisels.** A chisel is your metal-cutting troubleshooter. If you are unable to use snips or a hack saw for cutting, get a flat cold chisel. It can be used in restricted working areas and for such work as shearing off rivets, smoothing castings, or splitting rusted nuts from bolts. A cold chisel's cutting edge will cut any metal softer than itself.

9-7. The size of a flat cold chisel is determined by the width of the cutting edge. Lengths vary, but these chisels are seldom under 5 inches or over 8 inches long. In airframe repair work, the cold chisels most often used include the ¼-inch, ½-inch, and 1-inch sizes. Cold chisels are usually made of octagonal (eight-sided) tool steel bar stock carefully hardened and tempered. The cutting edge is slightly convex. This causes the center portion to receive the greatest shock when cutting and protects the weaker corners.

9-8. Keep your chisels sharp and the edges ground at the proper angle. The point angle should be 60° to 70° for general use, such as cutting wire, strap iron, or small bars and rods. If your work involves cutting keyways, square corners, or slots, use a special cold chisel, the cape chisel. It is like a flat chisel except that the cutting edge is very narrow. It has the same point angle and is held and used in the same manner as any other chisel.

9-9. Rounded or semicircular grooves and corners which have fillets should be cut with a roundnose chisel, which is illustrated in figure 29. This chisel is also used to draw back a drill that has moved away from its intended center.

9-10. The diamond point chisel (fig. 29) is tapered square at the cutting end, then ground at an angle to provide the sharp diamond point. It is used for cutting B grooves and inside sharp angles. When sharpening a chisel, hold it against the grinding wheel with very little pressure to avoid overheating. Dip the point in water often enough to keep it cool. Otherwise, the heat generated will "draw" the temper of the steel. If this happens, the cutting edge becomes soft and useless until rehardened and tempered.

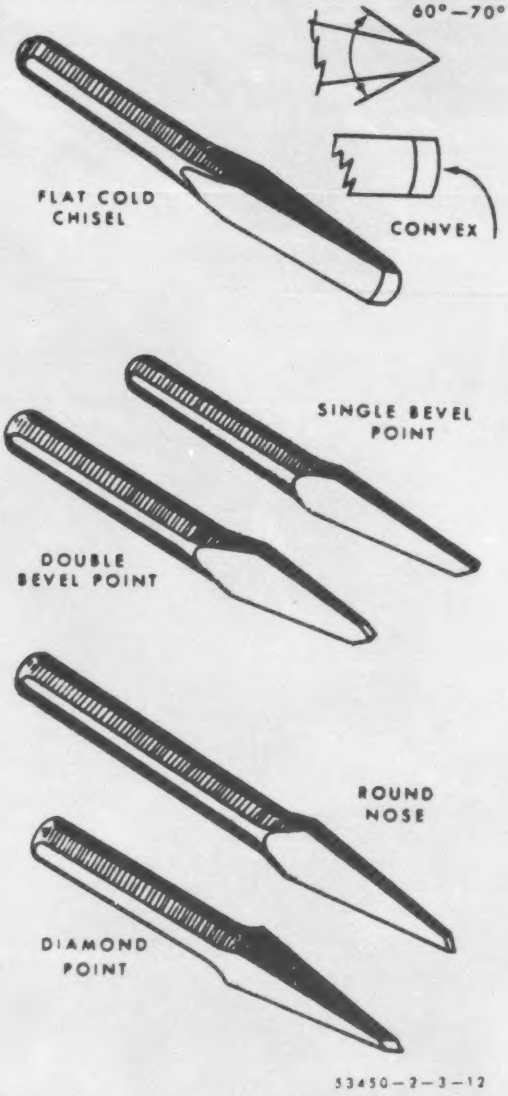


Figure 29. Chisels.

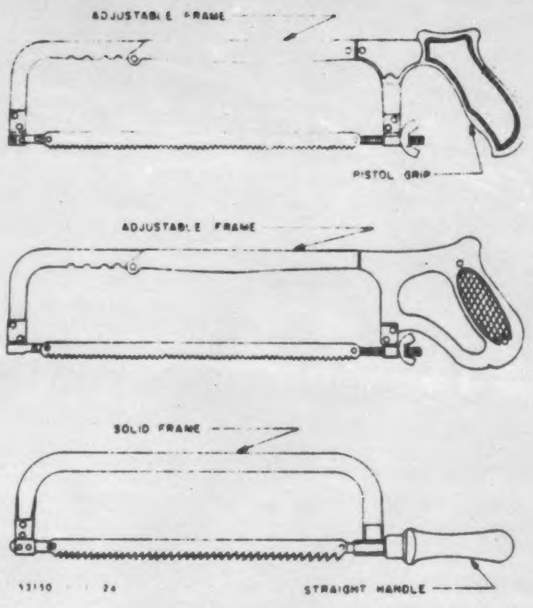


Figure 30. Hand hack saws.

9-11. Through normal use, the head of the cold chisel will spread out until it looks like a ragged mushroom. This spreadout head is rough and will "ream out" the inside of your hand if the chisel slips. Also, blows of the hammer may break off pieces from the overhanging mushroom and cause injury. Keep the head of the chisel dressed to eliminate these hazards.

9-12. **Hand Hack Saws.** The hack saws illustrated in figure 30 can be obtained in two styles, pistol grip and straight. The hand hack saws consist of a frame, handle, and blade. Hack saw blades come in lengths of 6 to 16 inches, although the 10-inch size is most commonly used. These blades are identified by length of blade and the number of teeth per inch (or pitch). Blades with 14, 18, 24, and 32 teeth per inch are available. Blades are made of high-grade tool steel, which may be flexible or all-hard. In flexible blades, only the teeth are hardened. Blade selection involves finding the right type for the job to be done, as illustrated in figure 31. An all-hard blade is best suited for sawing brass, tool steel, cast iron, and heavy cross sections of material. Flexible blades are recommended for sawing hollow shapes and material having a thin cross section. The selection of teeth is important. The following example will aid you in making the

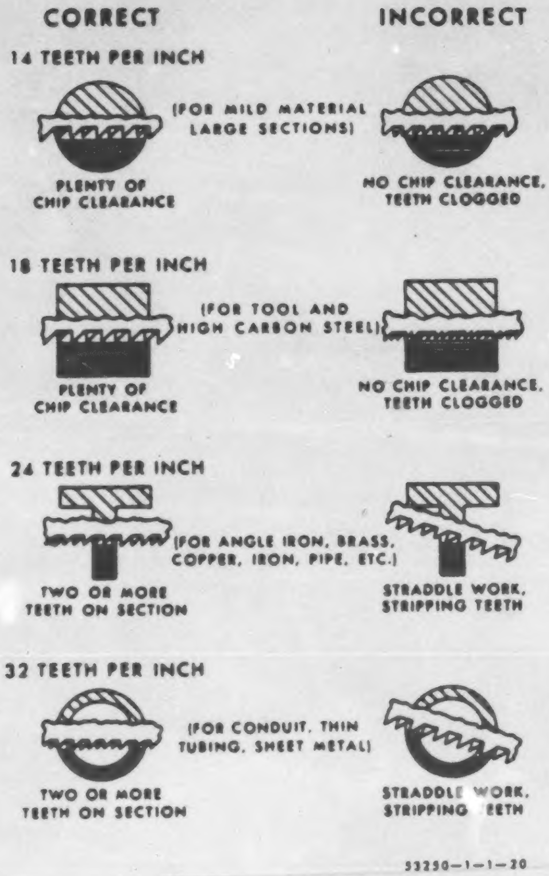

CORRECT
INCORRECT
14 TEETH PER INCH
(FOR MILD MATERIAL LARGE SECTIONS)
PLENTY OF CHIP CLEARANCE
NO CHIP CLEARANCE, TEETH CLOGGED
18 TEETH PER INCH
(FOR TOOL AND HIGH CARBON STEEL)
PLENTY OF CHIP CLEARANCE
NO CHIP CLEARANCE, TEETH CLOGGED
24 TEETH PER INCH
(FOR ANGLE IRON, BRASS, COPPER, IRON, PIPE, ETC.)
TWO OR MORE TEETH ON SECTION
STRADDLE WORK, STRIPPING TEETH
32 TEETH PER INCH
(FOR CONDUIT, THIN TUBING, SHEET METAL)
TWO OR MORE TEETH ON SECTION
STRADDLE WORK, STRIPPING TEETH
53250-1-1-20

Figure 31. Correct sawtooth selection.

correct selection. A blade with 14 teeth per inch is recommended for cutting cold roll and structural steel. The 18-teeth-per-inch blade is recommended for solid stock aluminum and cast iron. The 24-teeth-per-inch blade is recommended for cutting thick wall tubing, pipe, channel iron, and angle iron, as well as brass and copper. The blade you will most often use is the 32 teeth per inch which is recommended for thin wall tubing and light gage sheet stock.

9-13. Hack saw blades have holes in both ends. They are mounted on the frame by means of pins attached to the frame. When you install a blade in a hacksaw frame, always remember to install the blade with the angle of the teeth forward (away from the handle). After installation of the blade, adjust the tension. You must adjust the tension on the blade to prevent the saw from buckling and drifting.

9-14. When using a hand saw, you obtain best results if you clamp the material to be cut in a vise in such a way that it will provide as much bearing surface as possible and will engage the greatest number of teeth on the blade. Indicate the starting point by nicking the surface of the material to be cut with the edge of a file to break away any sharp corner that might tend to strip the teeth. This mark will also aid in starting the saw at the proper place. Hold the saw at an angle that will keep at least two teeth in contact with the work at all times. Start the cut with a light, steady, forward stroke just outside the cutting line. At the end of the stroke, relieve the pressure and draw the blade back. (The cut is made on the forward stroke.)

9-15. After the first few strokes, make each stroke as long as the hack saw frame will allow. This will prevent the blade from overheating. Apply just enough pressure on the forward stroke to cause each tooth to remove a small amount of metal. The strokes should be long and steady with a speed of not more than 40 or 50 strokes per minute.

9-16. **Power Hack Saws.** The manually operated hack saw has limitations not associated with the use of the power hack saw illustrated in figure 32. Power hack saws are designed to cut pipe, angle iron, bar stock, and heavy plate. The power hack saw is equipped with an adjustable viselike clamp to secure the material being cut. The clamp can be set for various miter cuts but is usually used to make 90° cuts. The blades are approximately 1 inch wide and come in various lengths. The number of teeth per inch for power

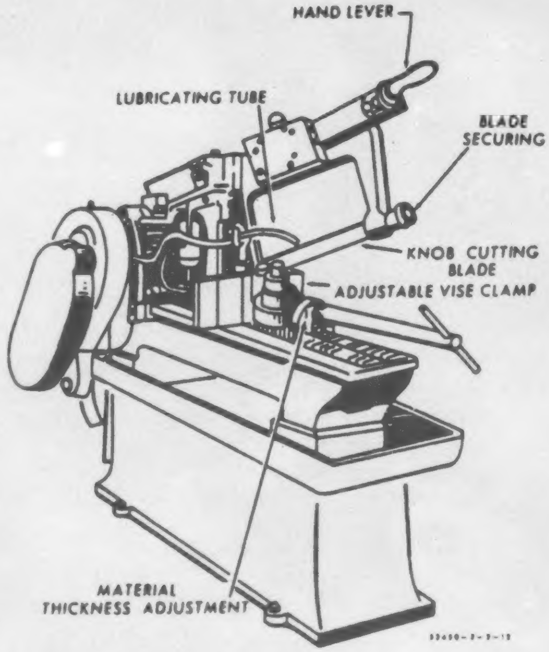

HAND LEVER
LUBRICATING TUBE
BLADE SECURING
KNOB CUTTING BLADE
ADJUSTABLE VISE CLAMP
MATERIAL THICKNESS ADJUSTMENT

Figure 32. Power hack saw.

hack saw blades is selected by the same criterion as that for hand hack saw blades. As with other machines, you should read the operator's instructions or the technical manual before using this machine.

9-17. Before starting the power hack saw, be sure that the material is clamped securely to prevent binding or breaking the blade. The material thickness adjustment is set in various notches according to the material thickness. A blade broken while the saw is operating improperly may shatter, endangering personnel. If your power hack saw is equipped with a blade lubricating device, be sure to keep the fluid strainer clean and to mix the cutting oil according to the manufacturer's specifications. Proper use of cutting oil means longer blade life and improved performance.

9-18. Several steps in power hack saw operation result from adjustments that must be made as a part of the operating procedure. The hydraulic control lever, mounted on the hydraulic unit, has three positions: normal (or neutral), center (or vertical), and feed. When the lever is as far back as possible, it is in the normal or neutral position. This position permits the saw arm to be moved up and down manually and disengages the clutch. When the lever is in the center or vertical position, the clutch is disengaged and the saw arm is hydraulically locked. When the clutch is engaged, the saw arm will reciprocate and feed downward when the control arm is placed in the feed position.

9-19. A catch or lock is provided to hold the control lever in both the vertical and feed positions. This catch or lock is engaged by holding the control lever away from the machine. It is disengaged by pressing it toward the machine.

9-20. Feed and pressure dials are used to govern the rate at which the saw descends and controls the feed automatically. The feeding action is actually affected more by the setting of the feed dial. The wider the section of stock to be cut, the greater the pressure dial setting that can be applied and vice versa. Always be careful to limit the pressure to a point where the blade cuts accurately.

9-21. You can bring the saw down to the work either hydraulically or manually. It can be brought down manually by placing the control lever in the normal or neutral position. An automatic knockout and height gage is incorporated in the hydraulic unit to provide an automatic means of disengaging the clutch. The knockout is actuated by the saw guide, which encounters an adjustable nut on the threaded knockout rod.

9-22. Speeds of approximately 65, 95, and 130 strokes per minute are available through a 3-speed transmission. The high speed is used for cutting nonferrous metals and mild or cold-rolled steel. The medium speed is for cutting tool steels and alloys. The low speed is for cutting high-speed tool steels, high nickel, chrome or manganese steels, and stainless steels.

9-23. Blades of various types are used. However, high-speed steel, molybdenum steel, or alloy high-speed blades are recommended. It is also recommended that you use a blade 14 inches long, 1 to 1-¼ inch wide, of 0.065 gage, with 4 or 6 teeth per inch. The blade must be kept tight at all times to prevent wobble and binding.

9-24. **Contour Band Saw.** Your shop probably has a contour band saw. The contour band saw, such as the DOALL shown in figure 33, is designed to make straight or irregular cuts. The DOALL is used in the repair and replacement of aircraft fittings or parts made of a material too heavy to be stamped out or cut by shears. It can also be used to advantage when a number of similar parts are to be cut from sheet stock. For this operation, fasten roughly cut pieces of sheet metal together by weld, solder, rivets, or clamps, and cut all the pieces at the same time. With the proper blade, and using the job selector dial as a guide, you may adjust this machine to cut many types of metal. The saw illustrated may be hand or power fed; however, you will use the manual feed process most of the time. Safety, especially with this machine, is a must.

9-25. The contour band saw has several speeds, both hand and automatic feeds, and an arrangement by which the table can be adjusted to any angle. Some saws are equipped with butt

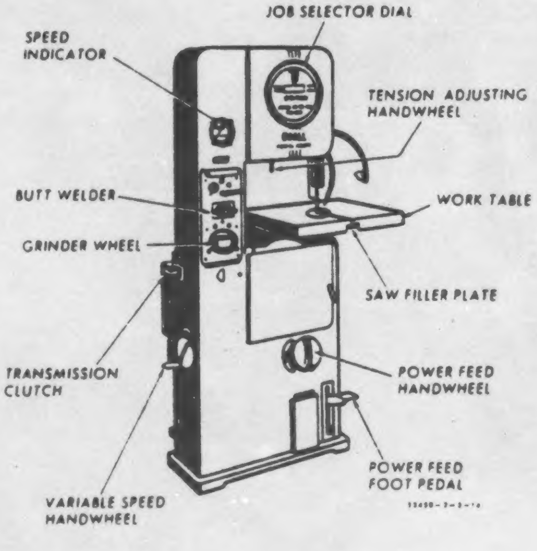


Figure 33. Contour band saw.

welding and grinding attachments which permit the saw blade to be set, inserted, and welded without delay when making internal cuts. This equipment can also be used to mend broken blades. Continuous file bands and polishing bands are available as accessories for finishing parts once they have been cut.

9-26. Cutting blades for the contour band saws are obtained from rolled blade stock, cut to length, butt welded at the ends, and run continously on wheels and through guides. If the blade is broken or a new blade is installed, this machine is capable of fabricating its blades from that blade stock, smoothing the excess from the butt weld to fit the guides, and retempering the blade after the fabrication operation. When installing or fabricating these blades, use the manufacturer's handbook or technical order to insure proper installation.

9-27. Installing a band saw blade is a simple process, but definite procedures should be followed. First, lower the upper wheel by means of the blade tensioning handwheel. (Lower the wheel enough to insure that the blade will fit around both the upper and lower wheels.) Grasp the right-hand portion of the blade in both hands, with the hands spaced about 10 inches apart. Pass the blade into the table slot. Be sure the teeth on the portion of the blade in your right hand are pointing toward you and downward.

9-28. As the blade approaches the front table trunnion, tilt the portion of the blade above the table to the right and the portion under the table to the left. Tilting the blade in this manner allows it to pass the front table trunnion. After the blade has passed the trunnion, return the blade to an upright position so it will pass through the remainder of the slot and then into the opening in the center of the table.

9-29. Thread the upper portion of the blade between the telescoping guard and upper wheel and finally around the lower wheel. Hold the blade in position on the upper and lower wheel and increase the blade tension to the desired amount by means of the blade tensioning handwheel.

9-30. After the proper tension is obtained, the upper wheel must be adjusted (tilted) to provide proper tracking of the blade. Do this by standing to the right of the machine so that the blade tracking screw (located in the center of the upper wheel) can be reached with the right hand and the upper wheel with the left hand. Standing in this position will permit you to turn the wheel with your left hand, observe the blade position on the face of the upper wheel, and make adjustment with the blade tracking screw.

9-31. With the fingers of your left hand placed against the surface of the flat wheel near the rim, rotate the wheel clockwise very slowly and observe the action of the blade. If the blade creeps toward one edge, turn the tracking screw so it will counteract the creeping tendency of the blade. Repeat this procedure until the blade runs in the center of the upper wheel as the wheel is rotated.

9-32. After you have completed the tracking operation as best you can while rotating the wheel manually, it is advisable to make a final adjustment of blade tension and follow up with a recheck of blade tracking.

9-33. The tracking adjustment is not completed until you are sure the blade will stay on when the wheels are turning at high speeds. Check this by replacing the upper and lower wheel covers and pressing the START button to start the motor. After the motor has gained a little speed, press the STOP button and check to see if the blade is tracking near the center of the upper wheel. Do not let the motor accelerate above one-half maximum speed until you are sure the blade is tracking properly. After the new blade is installed and tracking properly, make the necessary guide adjustments before using the saw. As with other metal-working machines, keep your hands and fingers clear of the cutting blade. Since band saw operation involves an eye hazard, you must wear goggles or a faceshield. Make certain that you are properly checked out before attempting any of the tasks needed to set up the band saw or before operating these machines.

9-34. **Ketts Circle Saw.** The circular cutting Ketts saw illustrated in figure 34 is portable, electrically operated, and uses blades of various diameters. The following are some of its advan-

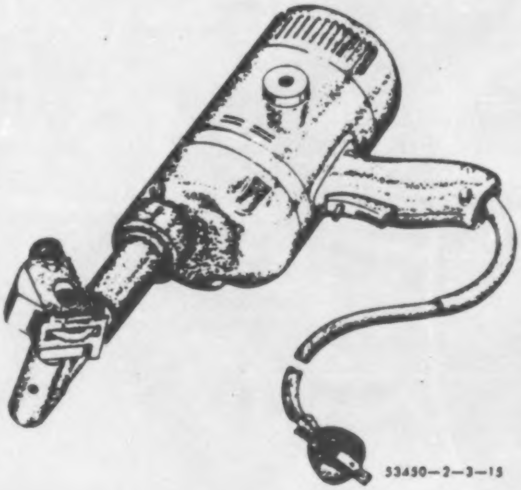


Figure 34. Ketts circle saw.

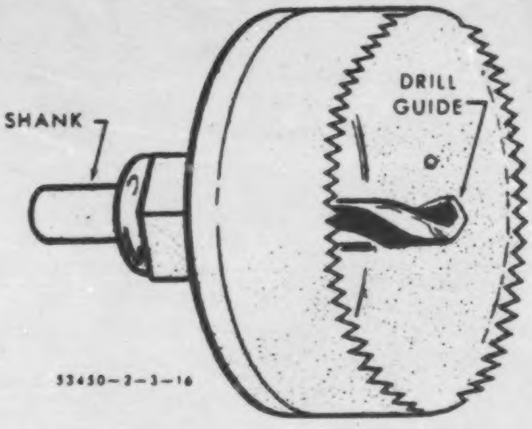


Figure 35. Hole saw.

tages: It can cut metal up to $\frac{3}{16}$-inch thick; it does not need a starting hole; a cut can be started anywhere on a sheet of metal; and it will cut an inside or outside radius. The head of the saw can be turned to any desired angle; it is very handy for removing damaged sections of a stringer.

9-35. If you do not maintain a firm grip on the saw handle while cutting, the saw will grab the material and may injure you or damage the metal. The most important thing to remember, before you use the saw, is to check the blade for cracks prior to installation. A cracked blade can fly apart and result in serious injury to people nearby.

9-36. **Hole Saws.** Hole saws, such as illustrated in figure 35, are used to cut holes in light-gage sheet metal stock and wood. They may be obtained in sizes up to 4-inch diameter. A ¼-inch drill is recommended for hole saw sizes up to 1½ inches, and a ½-inch drill is recommended for sizes up to 4 inches in diameter. This saw is very adaptable for cutting holes in skins and sheet stock to be used for panels and cover plates, since these items are usually fabricated with light-gage metal. When drilling with hole saws, use only enough pressure to cut evenly. Too much pressure will cause the saw to bind and create excessive strain on the saw and metal.

9-37. **Circle Cutters.** Circle cutters, like those illustrated in figure 36, are used with slow-speed pressure in both portable drills and drill presses in a similar manner and for the same purpose as the hole saws. However, the circle cutter differs from the hole saw in one respect—the circle cutter may be adjusted for different sizes and depths of cuts. In figure 36 you see the setscrew wrench, used to loosen and tighten the setscrews or to remove the twist drill. The adjustable arm enables the circle cutter to be used for cutting circles of different sizes, and raising or lowering the cutting blade makes it possible to regulate the depth of the cut. During use, the circle cutter must be held firmly and perpendicular to the material being cut, and the material must be securely held or clamped. Circle cutters are sometimes called fly cutters.

9-38. **Reciprocating Saw.** This saw, illustrated in figure 37, is portable, air-powered, and has a gun type shape for balancing and ease of handling. It operates most effectively if the supply of air pressure is from 85 to 100 pounds per square inch. It uses a standard hack saw blade cut to proper size, and, because of the adjustable collar, can be used to cut either a 360° circle, a square hole, a rectangular hole, or any degree of inside or outside cut. This saw, because of its shape, is easy to handle and safe to use with minimum safety procedures.

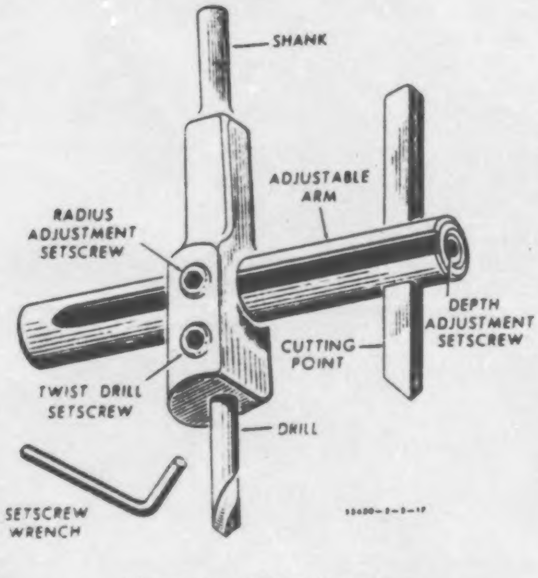


Figure 36. Circle (fly) cutter.

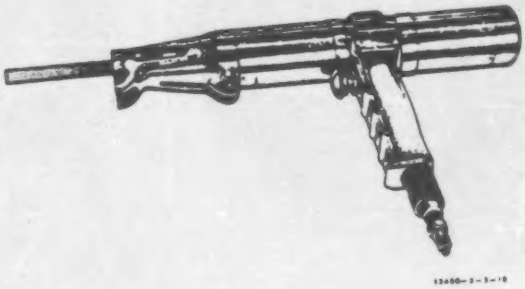


Figure 37. Reciprocating saw.

9-39. A reciprocating saw is used in such a way that at least two teeth are on the cutting surface at all times. When cutting with the reciprocating saw, avoid applying too much downward pressure on the saw handle, as this may cause the blade to break or bend.

9-40. **Nibblers.** Stationary and portable nibblers are used to cut metal by high-speed blanking action. The cutting or blanking action is caused by the lower die, moving up and down, meeting the upper stationary die. The shape of the lower die permits small pieces of metal approximately 1/16 inch wide to be cut out.

9-41. Nibbler cutting speed is controlled by the thickness of the metal being cut. Sheets of metal with a maximum thickness of 1/16 inch and a minimum radius of ½ inch can be cut satisfactorily. Too much force applied to the metal during cutting operations clogs the dies, causing die failure or overheating of metal.

9-42. Adjust the spring loaded screw on the base of the lower die so that the metal moves freely between the dies. This adjustment must be sufficient to hold the material firmly enough to prevent irregular cuts. You may shim the dies for special cutting operations.

9-43. Now turn to the workbook and answer the exercises for this section.

10. Drill Fixtures

10-1. Nearly all fabrications and installations of sheet metal components involve the drilling of holes; therefore, you must be familiar with the tools and equipment used and the operations involved. It is important for you to use the correct terms when speaking or writing about drilling equipment. For example, the word "drill," when used loosely, may cause some confusion in communication. A twist drill is the part that cuts the hole, whereas a hand drill, a portable drill (air or electric), or a drill press will supply the rotary motion and torque to rotate the twist drill.

10-2. **Hand Drills.** Hand drills are used to drill holes in light gage sheet stock. The chuck will normally accommodate a twist drill up to ¼-inch diameter. Hand drills are often used on jobs where only one or two holes are to be drilled, since the holes can be drilled in less time than it would take to set up a power unit for a pneumatic (air) drill. There will be occasions in your airframe work when power is not available and the work area cannot be reached with an airhose.

10-3. **Portable Pneumatic Drills.** You will find that a small portable pneumatic drill is usually the most practical machine to use in airframe work. Portable drills are manufactured in several sizes, which include ¼, ⅜, and ½ inch, as illustrated in figure 38. The ¼-inch drill is used extensively when drilling holes for rivets, screws, small bolts and other small fasteners. A ⅜- or ½-inch drill should be used to drill holes larger than ¼ inch. Pneumatic drills are generally used away from the shop, so be sure that an adequate

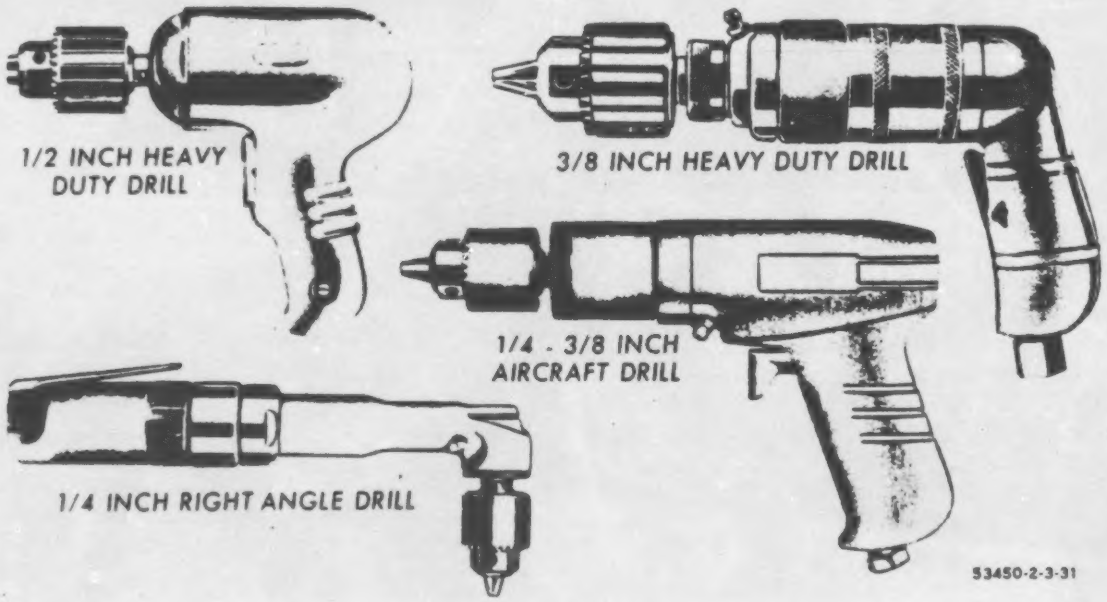

1/2 INCH HEAVY DUTY DRILL
3/8 INCH HEAVY DUTY DRILL
1/4 - 3/8 INCH AIRCRAFT DRILL
1/4 INCH RIGHT ANGLE DRILL
53450-2-3-31

Figure 38. Portable pneumatic drills.

supply of air is available before proceeding with the job.

10-4. When using a portable pneumatic drill, be sure the twist drill is firmly tightened in the geared chuck of the drill to prevent the twist drill from turning in the chuck, and thus prevent damage to the drill shank. First tighten the chuck handtight then insert the chuck key and tighten in each of the three holes. Do not overtighten with the chuck key, because the chuck threads can be damaged.

10-5. When using the hand pneumatic drill, hold it firmly and place a backup block of wood under the hole location (when possible) to add support to the metal. Insert the twist drill in the chuck and test it for trueness and vibration. You may check the trueness visibly by running the motor freely. Do not use a twist drill that wobbles or is slightly bent, because such a condition will cause enlarged holes. Always hold the drill at right angles to the work, regardless of the position or curvature. Tilting the drill at any time when drilling into or withdrawing from the material may cause elongation (egg shape) of the hole.

10-6. When drilling through sheet stock, small burrs are found around the edge of the hole. You must remove these burrs to prevent scratching and to allow rivets or bolts to fit snugly. Burrs may be removed with a countersink, a reamer, or a twist drill larger than the hole. If any of these is used to remove burrs, it should be rotated by hand.

10-7. Pneumatic drills are recommended for use by airframe repairmen because most of our projects are located around flammable materials. Sparks from electric drills are a fire hazard.

10-8. When access to a place where a hole is to be drilled is difficult or impossible with a straight drill, various types of drill extensions and adapters are available to you. A straight extension can be made from an ordinary piece of drill rod. The twist drill is attached to the drill rod by shrink fit, brazing, or silver soldering. Angle adapters can be attached to either an electric or pneumatic drill when the location of the hole is inaccessible to a straight drill. Angle adapters have an extended shank which is fastened to the chuck of the drill. In use, the drill is held in one hand and the adapter in the other to prevent the adapter from spinning around the drill chuck. You can use a flexible extension (snake) for drilling in places that are inaccessible to ordinary drills. Its flexibility permits drilling around obstructions with a minimum of effort. CAUTION: Always wear safety goggles while drilling.

10-9. **Drill Press.** The drill press is a precision machine used for drilling holes that require a high degree of accuracy. It serves as an accurate means of locating and maintaining the direction of a hole to be drilled, provides the operator with a feed control lever to regulate the drilling pressure, and makes the task of feeding the drill into the material easier. Among the many types of drill presses available, the most common type is the ordinary upright drill press, shown in figure 39.

10-10. When you use a drill press, adjust the height of the working table to accommodate the height and thickness of the part to be drilled; then clamp the material into position so that the center punch mark is directly in line with the twist drill. Material or parts that are not properly clamped may bind on the drill and start spinning, which could possibly cause the loss of fingers or hands or cause serious cuts to the operator's arms or body. Always make sure that the part drilled is properly clamped to the drill press before starting drilling operations. As with other drills, you must always wear eye protection—goggles, safety glasses, or a face shield—while operating a drill press. However, with this piece of equipment, there is more danger to the eyes, because you work with smaller particles of metal.

10-11. Most drill presses are equipped with gears or multistep pulleys to provide a means of increasing or decreasing the speed of the spindle. Prior to changing the speed, you should stop a drill press. The drill press in figure 39 is shown with the belt guard removed. The drill press can be adjusted for different spindle speeds by changing the V-belt to different steps on the V-pulleys. Be sure to stop the motor before moving the belt from one step to another; and don't forget to check the belt adjustment before operating the drill press.

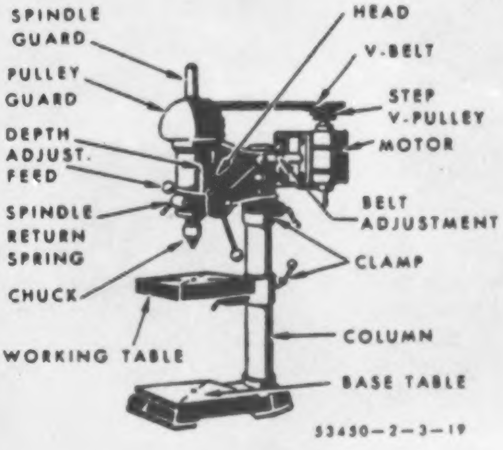


Figure 39. Drill press.

Size	Decimal Equivalent	Size	Decimal Equivalent	Size	Decimal Equivalent
1/2	0.500	3	0.213	3/32	0.0938
31/64	0.4844	4	0.209	42	0.0935
15/32	0.4688	5	0.2055	43	0.089
29/64	0.4531	6	0.204	44	0.086
7/16	0.4375	13/64	0.2031	45	0.082
27/64	0.4219	7	0.201	46	0.081
Z	0.413	8	0.199	47	0.0785
13/32	0.4062	9	0.196	5/64	0.0781
Y	0.404	10	0.1935	48	0.076
X	0.397	11	0.191	49	0.073
25/64	0.3906	12	0.189	50	0.070
W	0.386	3/16	0.1875	51	0.067
V	0.377	13	0.185	52	0.0635
3/8	0.375	14	0.182	1/16	0.0625
U	0.368	15	0.180	53	0.0595
23/64	0.3594	16	0.177	54	0.055
T	0.358	17	0.173	55	0.052
S	0.348	11/64	0.1719	3/64	0.0469
11/32	0.3438	18	0.1695	56	0.0465
R	0.339	19	0.166	57	0.043
Q	0.332	20	0.161	58	0.042
21/64	0.3281	21	0.159	59	0.041
P	0.323	22	0.157	60	0.040
O	0.316	5/32	0.1562	61	0.039
5/16	0.3125	23	0.154	62	0.038
N	0.302	24	0.152	63	0.037
19/64	0.2969	25	0.1495	64	0.036
M	0.295	26	0.147	65	0.035
L	0.290	27	0.144	66	0.033
9/32	0.2812	9/64	0.1406	67	0.032
K	0.281	28	0.1405	1/32	0.0312
J	0.277	29	0.136	68	0.031
I	0.272	30	0.1285	69	0.0292
H	0.266	1/8	0.125	70	0.028
17/64	0.2656	31	0.120	71	0.026
G	0.261	32	0.116	72	0.025
F	0.257	33	0.113	73	0.024
E-1/4	0.250	34	0.111	74	0.0225
D	0.246	35	0.110	75	0.021
C	0.242	7/64	0.1094	76	0.020
B	0.238	36	0.1065	77	0.018
15/64	0.2344	37	0.104	1/64	0.0156
A	0.234	38	0.1015	78	0.016
1	0.228	39	0.0995	79	0.0145
2	0.221	40	0.098	80	0.0135
7/32	0.2188	41	0.096	--	------

53150—1—3—119

Figure 40. Twist drill sizes.

10-12. You should avoid continued, heavy feed and excessive speed, because these will cause the machine to labor. These procedures may also cause twist drill breakage or damage to the machine. Speed of the chuck and rate of feed through the material vary, depending on the material you are drilling. Check the manufacturer's handbook or the technical manual for information concerning the feeds and speeds recommended for various drilling operations. When drilling hard metal or steels, use a cutting oil to cool and prevent dulling the twist drill. With proper feed and speed, the drill will usually produce a spiraled shaving; however, granular cuttings will be produced when drilling cast iron or other porous materials. To prevent binding or breakage, always reduce feed or pressure just before going through the metal.

10-13. Preventive maintenance for a drill press includes keeping it cleaned, adequately lubricated, and properly adjusted. A drill press, such as that illustrated in figure 39, should be inspected. Be sure that the belt guard is installed, that the V-belt has the correct tension, that the machine is clean, and that all parts operate and are serviceable. The motor of the drill press illustrated has sealed bearings and does not require oiling; however, the spindle and the depth adjustment feed handle have oil cups for lubrication. Lubricate the support column with an oiled rag to prevent corrosion and to allow the working table and head assembly to move up and down freely. Usually the V-belts on this type of equipment are adjusted to have a deflection of approximately ½ inch. Improper tension could cause a belt to break or fail to turn the spindle. To adjust the belt tension, loosen the belt adjustment nut, then tighten it after the proper distance between the pulleys has been obtained.

10-14. Before we continue to Section 11, turn to the workbook and answer the exercises for this section.

11. Twist Drills

11-1. Twist drills may be made of carbon steel or of high-speed alloy steel. Although carbon steel twist drills are satisfactory for general work, if heated excessively, they lose their hardness; however, high-speed steel drills may become very hot and still retain their temper. High-speed drills have the letters "HS" stamped on the shank to distinguish them from carbon drills. If you are drilling holes in hard or thick metal, it is desirable to apply a few drops of cutting oil in the hole for lubrication and prevention of excessive heating. If a cutting oil is used, high-speed twist drills will keep right on cutting even though they are hot. Excessive heating will also result from using a dull twist drill or from too much or too little pressure on the twist drill. If a high-speed twist drill becomes overheated, it should be allowed to cool slowly. Do not cool an overheated high-speed twist drill in water, oil, or fast moving air because the metal may crack.

11-2. Twist drill sizes are expressed in terms of numbers, letters, and inches or fractions of inches, as shown in figure 40. The size is stamped on the shank of the twist drill. For example, a $^{3}/_{16}$-inch twist drill, often used in sheet metalwork, has a decimal equivalent size of 0.1875 inch.

11-3. Figure 41 shows a twist drill with the nomenclature of its parts, including the shank, body, heel, flute, and land. A twist drill for most operations has a lip angle of 59° and a heel angle of 12° to 15°. A lip angle of 68° is recommended for hard materials, such as stainless steel. Soft metals, such as brass or bronze, can be drilled with a twist drill having a lip angle between 50° to 60°. In sharpening a twist drill, both cutting edges must have the same lip angle and the same length cutting edge. The drill shank is the end that fits into the chuck of a drill motor or hand drill. The body is the part of the drill from the point to the shank, or from the point to where the flute ends. Flutes (channels) are designed in the drill to allow the chips, which are formed while drilling, to curl tightly and escape from the hole being drilled. These flutes also allow the lubricant to flow easily down to the lips of the drill, where it is needed as a coolant.

11-4. The lips (cutting edge) are the parts of the point which actually do the cutting. The drill axis, which runs from the center of the web to the extreme end of the shank, is the exact center of your drill. The web is the metal column which separates the flutes and is sometimes called the backbone of the drill. The point of a drill is the

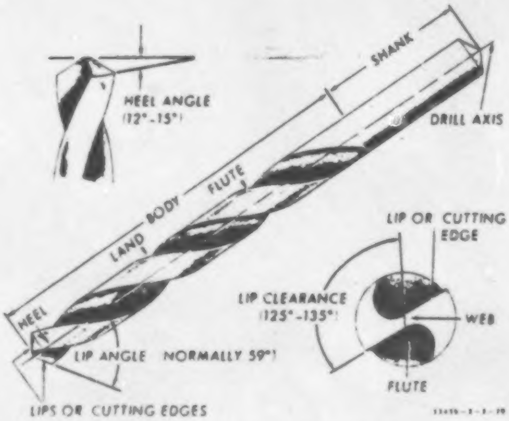


Figure 41. Twist drill nomenclature.

entire cone-shaped surface at the cutting edge. It should not be confused with the web. The heel is that part of a drill point just back of the cutting lips; its sole purpose is to allow the drill to work at its maximum effectiveness.

11-5. When you are drilling a hole with a twist drill installed in a hand or powered drill, the chuck must be tight enough to prevent slippage. The twist drill must make a hole with its center at the exact spot desired; therefore, you should use a center punch to sink a mark deep enough to prevent the twist drill from "walking" away from the center point. (Be careful not to dimple the material by striking the center punch too hard.) Next, secure the work and place the point of the twist drill into the punch mark. After drilling is begun, keep the drill at right angles to the surface of the work throughout the operation. You should ease the pressure the instant the twist drill breaks through the material but continue drilling until the hole is finished. Follow the previously indicated procedures to keep the twist drill from overheating.

11-6. **Sharpening.** Correct twist drill grinding is an absolute must, because a sharp twist drill performs more efficiently and you can attain a higher quality of work with less physical application on the drill. You cannot turn a twist drill in to Supply just because the point is dull. Drills, at this time, are classified as expendable items and can be replaced only after normal wear or breakage. Two methods of sharpening twist drills concern you as an airframe repairman—the drill-holding fixture type and free-hand grinding.

11-7. *Drill-holding fixture.* The exact procedure for grinding when using the drill-holding fixture varies with the make of the grinding machine or tool used. The procedures outlined in the following paragraphs are general and can be applied to most conventional type machines.

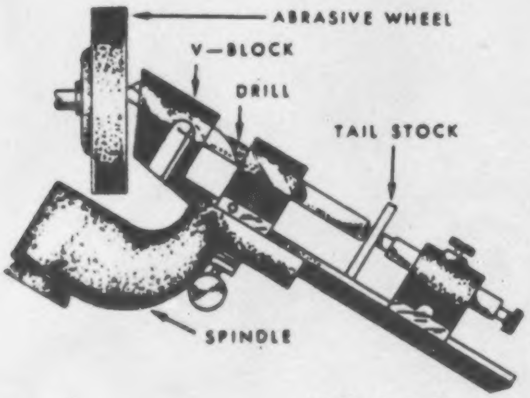


Figure 42. Using a drill holder fixture.

11-8. Place the drill in the V-blocks of the holder and turn the drill so that the cutting edge will contact the abrasive wheel as the drill is fed against the wheel. (See fig. 42.) Start the grinder and advance the tailstock until the drill makes contact with the abrasive wheel. Hold the drill in place in the V-blocks and swing the holder spindle slowly through its arc. Without changing the tailstock adjustment, revolve the twist drill one-half turn in the V-blocks and sharpen the other lip of the twist drill in the same manner.

11-9. Inspect the drill point to see if it has been ground back far enough to eliminate all nicks. Repeat the grinding and inspection operations until a perfect point is obtained.

11-10. *Free-hand grinding.* Free-hand grinding is done without the aid of any fixtures. The success of this operation depends upon your skill in using various techniques. Figure 43 illustrates the following procedures.

11-11. Adjust the tool rest of the grinder to a convenient height for resting the back of your left hand while you are grinding. Hold the drill between the thumb and index finger of one hand and grasp the body of the drill near the shank with the other hand. Place your left hand on the drill rest, with the center line of the drill making the desired angle with the cutting face of the grinding wheel, and then slightly lower the shank end of the drill as illustrated.

11-12. There are two ways of rotating the drill when grinding—counterclockwise and clockwise. The method used depends upon the individual. When rotating the drill in a counterclockwise direction, slowly place the heel of the drill against the grinding wheel. Then gradually raise the shank end of the drill and twist it in the fingers in a counterclockwise direction while the grinding wheel contacts the cutting edge. Exert only enough pressure to grind the drill without overheating. Frequently cool the drill in water while grinding. As you rotate the drill in a clockwise direction, hold the drill in the right hand, with the point against the grinding wheel at the proper angle. The left hand should hold the body of the drill in the same manner as for counterclockwise grinding. With the drill lip bearing against the grinding wheel, the right hand should push the shank of the drill down and at the same time rotate the drill slightly clockwise and push it forward slightly. Remember to dip the drill in water often enough to prevent overheating. Check the results of the grinding with a gage or equivalent tool to determine whether the cutting edges are the same length and at the desired

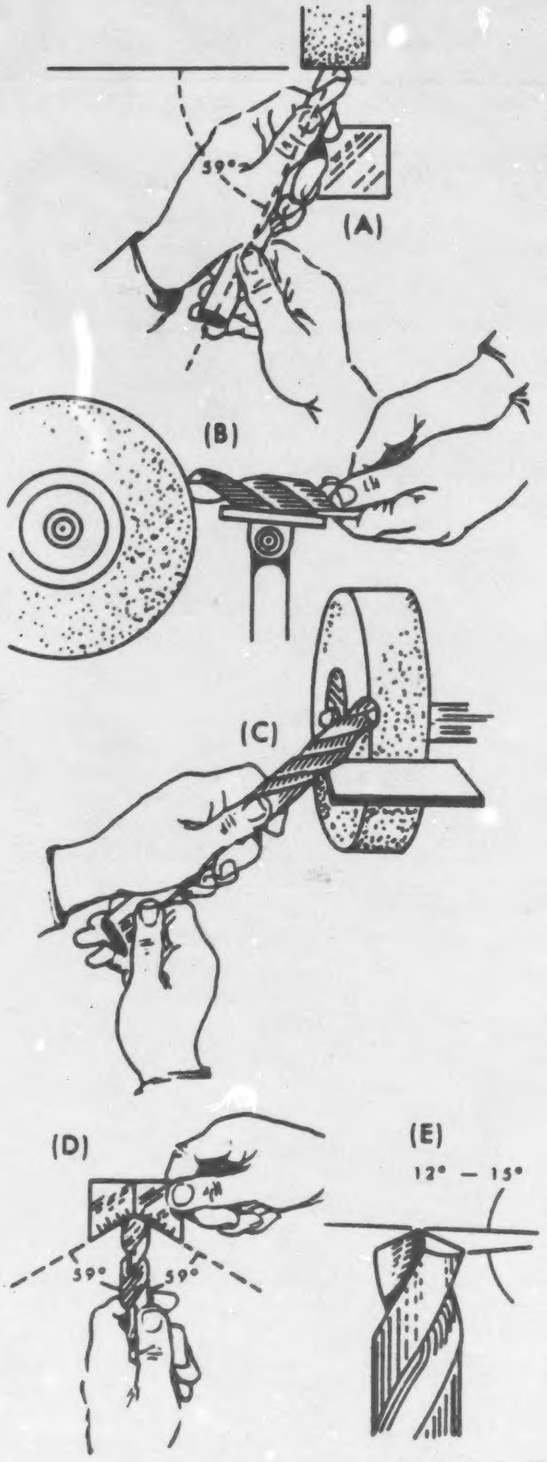


Figure 43. Drill sharpening procedures.

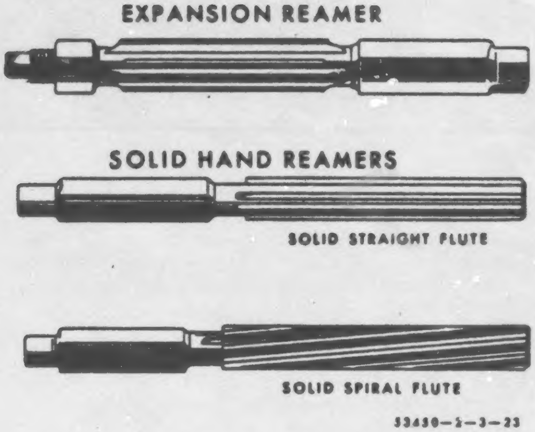


Figure 44. Reamers.

angle. Also notice whether the heel is ground to an angle of 12° to 15°.

11-13. The thickness of the web of a drill increases as the flute approaches the shank; this adds strength to the drill. As the drill point wears away through normal use, the web at the point becomes thicker. The web at the point should be no thicker than 1/32 or 1/16 inch. Web thickness can be controlled by grinding the web on a thin, round, or beveled edge wheel. If a suitable grinding wheel is not available, a corase hand stone can be used. If you use a hand stone, hold the drill flat on the bench and then stroke the flute away from the point. Regardless of how the web is ground, be sure to remove the same amount of metal from each flute, and only enough to acquire a web thickness the same as that of a new drill the same size.

11-14. **Reamers.** Reamers are used to smooth and enlarge holes to exact size. Hand reamers, illustrated in figure 44, have square end shanks so they can be returned with a tap wrench or similar handle. A hole that is to be reamed to exact size must be drilled about 0.003 to 0.007 inch under size. A cut that removes more than 0.007 inch places too much load on the reamer and should be avoided.

11-15. Reamers are made of either carbon steel or high-speed steel. The cutting blades of a high-speed steel reamer lose their original keenness sooner than those made of carbon steel; however, after the first extreme keenness is gone, they are still serviceable. The high-speed reamer usually lasts much longer than the carbon steel type. Reamer blades are hardened to the point of being brittle and must be handled carefully to avoid chipping them. When reaming a hole, rotate the reamer in the cutting direction only.

Turn the reamer steadily and evenly to prevent chattering, or marking and scoring the hole walls.

11-16. Reamers of the type illustrated in figure 44 are available in any standard size. The straight fluted reamer is less expensive than the spiral fluted reamer, but the spiral type has less tendency to chatter. Both types are tapered for a short distance back of the point to aid starting. Bottoming reamers have no taper; they are used to complete the reaming of blind holes. For general use, an expansion reamer is the most practical. This type is furnished in standard sizes from ¼ inch to 1 inch, increasing in diameters by 30 seconds. Each reamer has a maximum expansion of 1/32 inch. Taper reamers, both hand- and machine-operated, are used to smooth and true tapered holes and recesses.

11-17. Now turn to the workbook and answer the exercises for Section 11 before you continue to Section 12.

12. Punches

12-1. You will use several types of punches in airframe repair work, including those for marking metal before drilling, for removing pins and rivets, for aligning holes, and for piercing holes. Each punch is designed for a specific job. Hand punches driven with a hammer include the center punch, prick punch, starting drift punch, drift punch, pin punch, and hollow punch. Lever type punches that you will use are the Whitney punch and the rotary punch.

12-2. **Hand Punches.** There are many types of hand punches you can use; however, the punches illustrated in figure 45 are used more often than others. The heads and points should be kept in good condition in the same manner as chisels.

12-3. *Center punch.* The center punch is used to make a small depression on metal prior to drilling or punching. The depression prevents the twist drill from "walking" during the drilling operation. The punch should never be struck with such force as to dimple the material around the indention or to cause the metal to protrude through the other side of the sheet. A center punch has a heavier body than a prick punch and is ground to a point with an angle of about 60°.

12-4. *Prick punch.* The prick punch is used to establish location points when laying out patterns on sheet stock. This punch is often used to transfer dimensions from a paper pattern directly to the metal. To do this, first place the paper pattern directly on the metal. Then go over the outline of the pattern with your prick punch, tapping it lightly with a small hammer and making slight indentations on the metal at the major points on the drawing. These indentations can then be used as reference marks for cutting or folding the metal. A prick punch should never be struck a

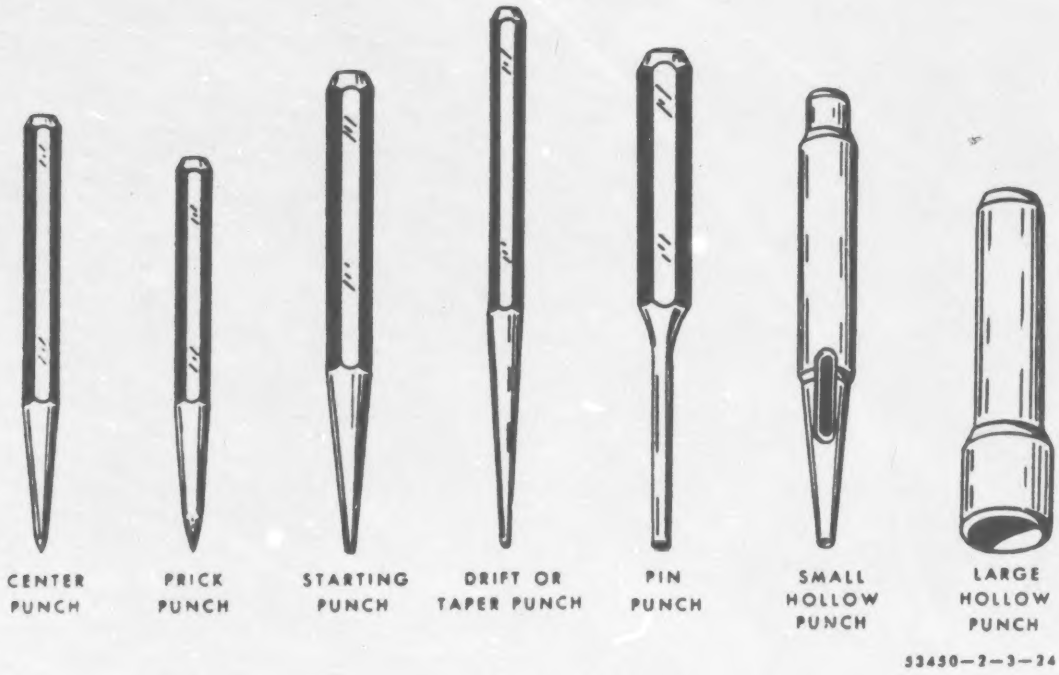


Figure 45. Hand punches.

heavy blow with a hammer because it may bend the punch or cause excessive damage to the material being worked.

12-5. *Starting punch.* The starting punch is tapered for strength, has a blunt tip, and is used to loosen tight-fitting pins that are to be removed from a hole.

12-6. *Drift punch.* A drift punch (taper punch) is also used to loosen tight-fitting pins, although its slender taper is not as strong as that of the starting punch. The drift punch is often used to align holes in two pieces of metal prior to installing screws, bolts, or rivets.

12-7. *Pin punch.* The pin punch has no taper; it is used to drive out rivets which have had the heads drilled off and to drive pins out of holes too deep for the starting punch or drift punch.

12-8. In general practice, a pin or bolt which is to be driven out is usually started and driven out with a drive punch until the sides of the punch touch the side of the hole. A pin punch is then used to drive the pin or bolt the rest of the way out of the hole. Stubborn pins may be started by placing a thin piece of scrap copper, brass, or aluminum directly against the pin and then striking it with a heavy hammer until the pin begins to move. Never use a prick punch or center punch to remove objects from holes, because the point of the punch will spread the object and cause it to bind even more.

12-9. *Transfer punch.* The transfer punch is usually about 4 inches long and has a point tapered and then turned straight for a short distance in order to fit a drill locating hole of a template. The tip of the transfer punch has a point similar to that of a prick punch. As its name implies, the transfer punch is used to transfer the location of holes through the template or pattern to the material.

12-10. *Hollow punch.* Hollow punches, with a suitable backup material, are used to pierce holes in thin sheet stock.

12-11. **Whitney Punch.** The leverage type hand punch has largely taken the place of hollow hand punches. The Whitney punch has interchangeable dies for piercing holes in metal. The Whitney punch, shown in figure 46, is used to punch light-gage metal and is available with dies ranging in size from $\frac{1}{16}$ to $\frac{9}{32}$ inch. When making holes in exact locations, set the centering point in the center punch mark. You will find that the Whitney punch will pierce holes much faster in light-gage metal than it is possible to do with twist drills. When changing punches and dies, be sure to match the sizes. A punch that is too large for a die will damage the cutting edges, and one that is too small will pierce the hole but dimple the material.

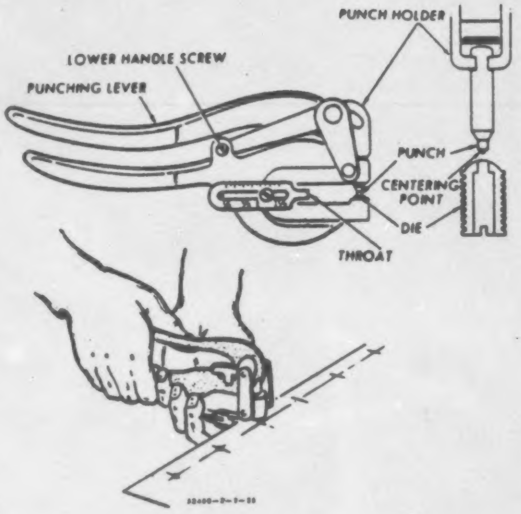


Figure 46. Whitney punch.

12-12. These leverage type punches are handy tools around the airframe repair shop, since they afford you a simple means of punching clean holes. There are a number of hand lever punches other than the Whitney illustrated in figure 46; the one in your shop may be different. When working with these punches, keep the working parts well lubricated to insure ease of working.

12-13. Most punches have an attached gage which consists of a guide and an adjustable scale. The scale graduation on the guide mark indicates the depth of the throat in inches—that is, the distance from the edge of the sheet stock to the center of the hole. This gage is not generally used, because you should first use a center punch to mark the position of the holes to be punched. Then you can easily feel this punch mark with the hand punch centering point. Never use a punch on material beyond the capacity of that particular punch.

12-14. Changing dies in a hand leverage type punch is a relatively simple matter. The bottom die is made with threads cut around the outside. This die screws into the lower tip of the throat jaws by means of a slot. By placing a screwdriver in this slot, you can move the die in or out as the need arises. The punch can be removed by taking out the pin or screw located just forward of the lower handle; then, by pushing the punch holder forward, you easily remove the punch die. To replace the punch, reverse the procedure. The basic handicap of the leverage type Whitney punch is that the punch has a short throat and can only be used when hole locations are near the edge of the material.

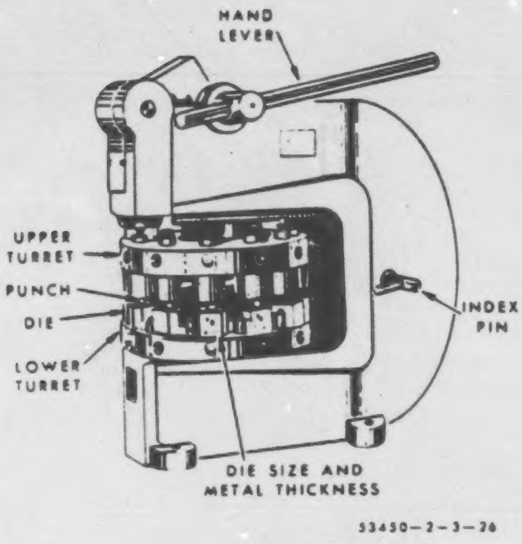


Figure 47. Rotary punch.

12-15. **Rotary Punch.** This large punch press is used in the airframe repair shop to punch holes in metal parts. It can also be used for cutting radiuses in corners and for making washers. The rotary punch press shown in figure 47 is found in most airframe repair shops. It is composed of two cylindrical turrets, one mounted over the other and supported by the frame. Both turrets are synchronized so that they rotate together, and the index pins maintain correct alignment at all times. To release the index pins from their locking position, the lever, which is located on the right side of the machine, is rotated through a 180° arc. This action will withdraw the index pins from the tapered holes and allow you to turn the turrets to any size punch desired.

12-16. To operate this rotary punch, place the metal between the die and punch. Then the hand lever, on the top right side of the machine, is pulled towards you. This will force the punch through the metal. When the lever is returned to its original position, the metal will be stripped off the punch.

12-17. Stamped on the front of each die holder is the diameter of the punch and its maximum capacity for punching mild steel. Each punch is made with a point which can be placed in the center punch mark. This point will assure you the definite location to be pierced.

12-18. To accurately align the punch and die, you must determine where the adjustment is necessary by punching through several thicknesses of stiff paper. This will show which side of the die has the greatest clearance. If the cut is uneven, loosen the lockscrews and tap the die in the opposite direction. When the paper is cut evenly all around, tighten the punch securely with the lockscrews which are located between each set of dies.

12-19. Preventive maintenance for the rotary punch consists mainly of keeping it cleaned, adequately lubricated, and properly adjusted. The rotary punch illustrated in figure 47 is periodically inspected to see that the index pin works freely and locks the upper and lower turrets easily. If necessary, clean and oil the index pin and align holes in the turrets. Inspect each punch and die to see if it lowers and raises freely when the hand lever is pulled forward. Cleaning and oiling are necessary for any that stick. For thorough cleaning, you must remove a sticking die or punch. Then clean the punch and its sleeve and lightly coat them with oil before reassembling. Inspect the hand lever and connecting linkage for cleanliness and freedom of operation; if necessary, clean and oil the moving parts. Inspect each punch for proper alignment with its corresponding die. Do this, as mentioned earlier, by punching several thicknesses of stiff paper. After inspection, wipe off all excess oil, clean all painted surfaces with a dry rag or a rag moistened with soap and water, and wipe all unpainted surfaces with a slightly oiled rag.

12-20. The principal safety precaution to observe when operating the rotary punch press is to keep your fingers away from the punch and die and return the hand lever to the full up position after each operation has been completed.

12-21. Before we go to Section 13, turn to the workbook and complete the exercises for this section.

13. Abrasive Tools

13-1. In the previous sections of this volume, we have frequently mentioned the metal burrs

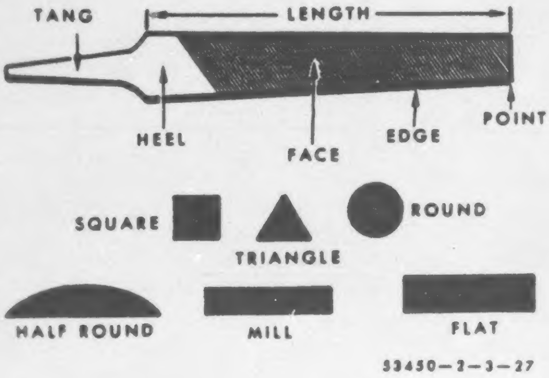


Figure 48. Shapes of files.

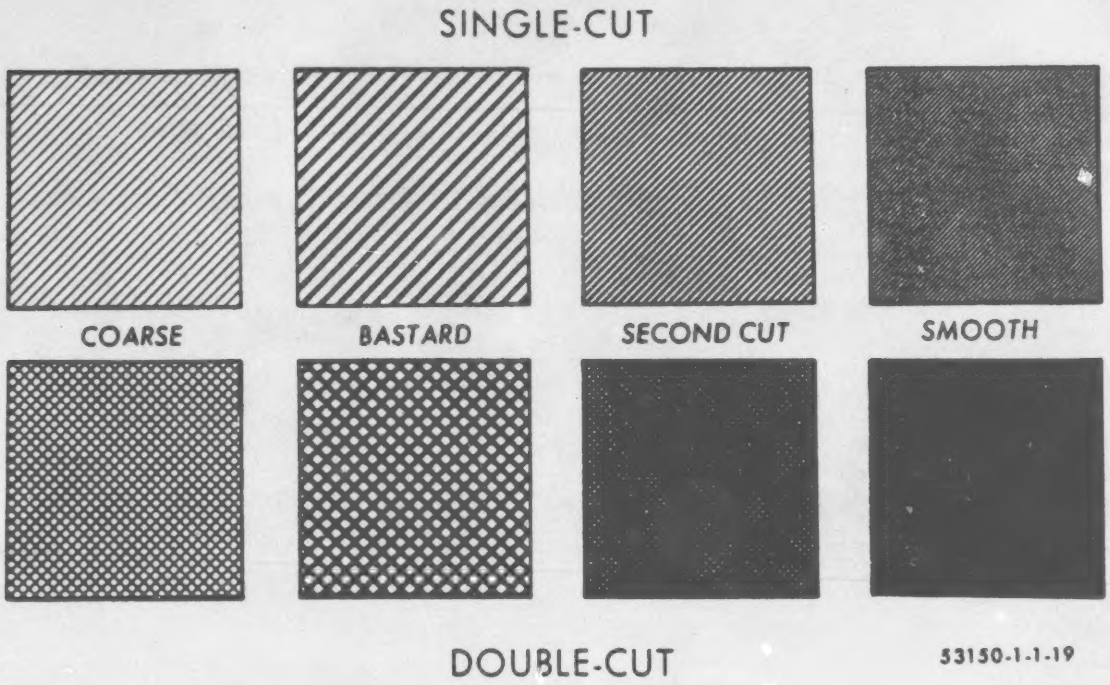


Figure 49. Types of file cuts.

often produced by cutting equipment. You were cautioned to avoid contact with these burrs, since they can easily cut your hands and fingers or snag your clothing. These rough edges can be removed with files, grinders, or rotary files.

13-2. **Files.** No shop or individual toolkit is complete without at least several files. Figure 48 illustrates six shapes of files most often used by airframe repairmen:

- Flat file—used to file flat surfaces and for other fast cutting operations.
- Mill file—especially adapted for finish filing.
- Triangular, or "three-cornered," file—used in filing internal angles and clearing out corners.
- Square file—most useful in finishing the bottom of slots.
- Round file (or ratrail)—used for enlarging round holes.
- Half-round file—used where other files will not fit.

13-3. Files are very useful tools, but their life and usefulness depend a great deal upon the way they are used and maintained. They should be cleaned frequently with a file card or brush and kept separated from other tools to prevent damage to the other tools.

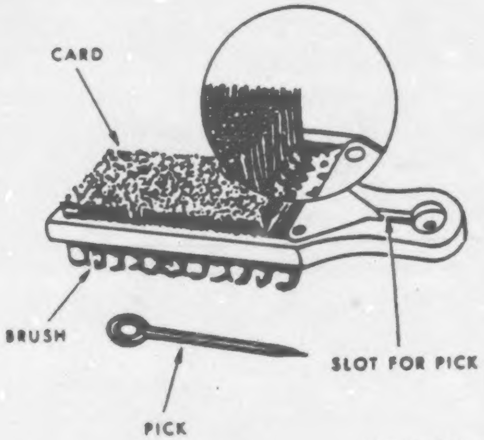
13-4. Files are usually made in two types of cuts: single-cut and double-cut, as shown in figure 49. The single-cut file has a single row of teeth extending across the face at an angle from 65° to 85° to the length of the file. The size of the cuts depends on the coarseness of the file. The double-cut file has two rows of teeth which cross each other. For general work, the angle of the first row is from 40° to 45°. The first row is generally referred to as "over-cut"; the second row is referred to as "up-cut," the up-cut being somewhat finer and not as deep as the over-cut.

13-5. Single-cut files are recommended for sharpening cutting tools, such as shear and snip blades. Light pressure should be applied to single-cut files to obtain a smooth finish. Double-cut files are used when a rough finish is permissible and heavy pressure may be applied for fast cutting. One of the factors in selecting a file is the composition of the metal to be filed. An example is stainless steel, which is hard and requires a file with a deep up-cut and fine over-cut.

13-6. A file has the following parts: tang, face, heel, and point, as illustrated in figure 48. Generally, all files are manufactured in the same way. A file flank of carbon steel is heated, the teeth are cut into it, and it is quenched in water to harden it. This method has the disadvantage of making the file brittle.

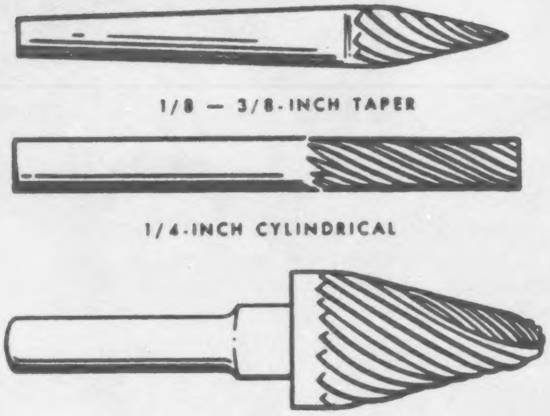
13-7. When using a file, hold the handle in the right hand with the fingers underneath and the thumb on top. The left hand should grip the point of the file between the thumb and fingers. This position may be used, but the job and location will determine the method you will want to use to get the job done satisfactorily. If possible, the work should be at the height of your elbow. This position will enable you to file in long, smooth strokes of approximately 60 per minute. Filing too fast will actually cause the points of the teeth to get hot enough to lose their hardness. Do not put pressure on the file as it is being drawn back over the material, because the teeth slant forward and the pressure on the back stroke will probably break them off. An exception to the rule is in the filing of very soft metals, such as lead, solder, or aluminum. When working with these metals, apply a slight pressure on the back stroke. Soft metals will not break the teeth, and the slight pressure aids in cleaning the file. Chips that stick in the teeth of the file can be easily removed with a file card. Figure 50 illustrates the two-part file card, used for cleaning material from the teeth of a file. You can also use a little oil or chalk on a file to help prevent chips from sticking to the teeth. Never use a file without a handle. A file with a handle is much easier to use and less likely to injure your hands. Never use a file as a pry or a hammer. The metal is too brittle and will probably break.

13-8. **Rotary Files.** Rotary files, such as those illustrated in figure 51, have ¼-inch-diameter shanks which can be "chucked" in a hand drill, a portable pneumatic drill, or a drill press. Rotary files with spiral cutting flutes, smaller than the spiral flutes of reamers, are more often used to ream or enlarge holes than to remove burrs. Although in most cases you will use a twist drill to enlarge holes in metal stock, on occasion it is desirable to use a rotary file instead. Selection of size and shape of the rotary file depends upon the job. For example, the rotary files illustrated in figure 51 can be used to ream holes, to elongate slots, and to file irregularly shaped edges.



53450-2-3-28

Figure 50. File card.



53450-2-3-29

Figure 51. Rotary files.

13-9. **Grinding Machines.** The term "grinder" is applied to all forms of grinding machines. To be specific, a grinder is a machine with an abrasive wheel which removes excess material while producing a suitable surface. We will discuss only those grinders which are helpful to the airframe repairman.

13-10. *Grinding wheel.* A grinding wheel is a cutting tool with a large number of cutting edges so arranged that, as they become dull, they break off and new cutting edges take their place. Four factors affect grinding wheels—the kind of abrasive, the size of the abrasive particles, the kind of bond, and the amount of bond.

13-11. Silicon carbide and aluminum oxide are the abrasives in most grinding wheels used by the airframe repairman. Silicon carbide is the cutting agent for grinding hard, brittle material, such as cast iron. It is also used in grinding aluminum, brass, bronze, and copper. Aluminum oxide is the cutting agent for grinding steel and other metal of high tensile strength.

13-12. The size of the abrasive particles used in grinding wheels is indicated by a number which corresponds to the number of meshes per linear inch in the screen through which the particles will pass. As an example, a number 30 abrasive will pass through a screen having 30 holes (meshes) per linear inch, but will be retained by a smaller screen having 60 holes per linear inch.

13-13. The bond is the material which holds the abrasive particles together in forming the wheel. The kind and amount of bond used determines the hardness or softness of the wheel. The commonly used bonds are the vitrified, silicate, resinoid, rubber, and shellac. Vitrified and silicate are used the most; vitrified bond is used in approximately three-fourths of all grinding wheels. This bonding material forms a very uniform wheel and is not affected by oils, acids, water, heat, or cold. The silicate bond, however, is best suited for grinding edged tools. Resinoid-bonded wheels are for heavy-duty grinding. Rubber-bonded wheels are used where a high polish is required. Shellac-bonded wheels are used to form grinding materials where a buffed or burnished surface is needed.

13-14. *Pedestal grinder*. A pedestal, or floor type, grinder usually has a grinding wheel on each end of a shaft which runs through an electric motor or a pulley operated by a belt. This grinder is used for sharpening tools and for other general grinding jobs.

13-15. *Wet grinder*. The wet grinder is similar to the pedestal grinder, but it has a pump to supply a flow of water on a single grinding wheel. Water reduces heat produced as the material is ground by the wheel. It also washes away any bits of metal or abrasive removed during the grinding operation. The water returns to a tank and can be reused.

13-16. *Bench grinder*. A common bench grinder found in most airframe repair shops is illustrated in figure 52. This grinder may be used to dress mushroomed heads on chisels, and points on chisels, screwdrivers, and drills. It may be used for removing excess metal from work and for smoothing metal surfaces.

13-17. In your shop you will probably find this type grinder equipped with one medium-grain and one fine-grain abrasive wheel. The medium wheel is usually used for rough grinding where a considerable quantity of material is to be removed or where a smooth finish is unimportant. The fine wheel is usually used for sharpening tools and grinding to close limits because it removes metal more slowly, gives the work a smoother finish, and does not generate enough heat to anneal the edges of cutting tools. When

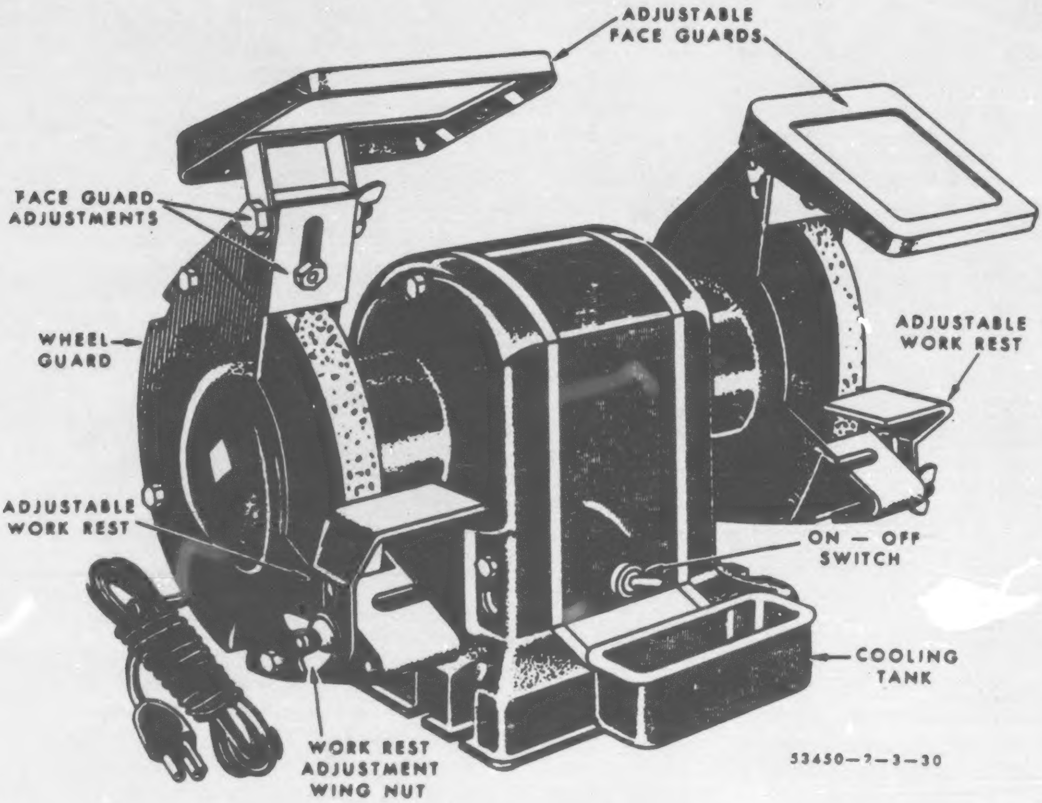


Figure 52. Bench grinder.

it is necessary to make a deep cut on work, or a large amount of metal is to be removed, it is usually good practice to grind with the medium wheel first and then finish with the fine wheel.

13-18. Grinding wheels are removable. Grinders are usually so designed that wire brushes, polishing wheels, or buffing wheels can be substituted for abrasive wheels.

13-19. As an airframe repairman, you must know the correct cutting edge angle of a tool before attempting to sharpen it. After determining the correct cutting angle, turn on the grinder switch and hold the work firmly at the correct angle on the tool rest provided. Feed the tool into the wheel with just enough pressure to remove the proper amount of metal without generating too much heat.

13-20. Grinders are very hazardous; be careful when operating them. You must not use the work rest when it is more than ⅛ inch from the grinding wheel. When starting a grinder, stand to the side until it attains operating speed. This protects you if a defective wheel disintegrates. If the grinder chatters or vibrates excessively, something is wrong; turn the power off at once.

13-21. As a rule, it is not good practice to grind work on the side of an abrasive wheel. When an abrasive wheel becomes worn, its cutting efficiency is reduced because surface speed decreases. Discard such a worn wheel and install a new one.

13-22. The bearings and motor of the bench grinder are provided with lubrication cups. Lubricate according to manufacturer's specifications.

13-23. Before using a grinder, make sure the abrasive wheels are held firmly on the spindles by the flange nuts. If an abrasive wheel were to come off or become loose, it could ruin the grinder and seriously injure the operator. Another safety hazard is loose tool rests. We mentioned earlier the operating distance of the rest, but if the rest is loose, it could cause the tool or piece of work to be "grabbed" by the abrasive wheel and cause the operator's hand to come in contact with the wheel. Severe wounds may result.

13-24. Always wear goggles, even if the machine is equipped with face guards. The only sure way to protect your eyes from the fine pieces of steel is to use goggles that fit firmly against your face and nose. Goggles that do not fit properly should be exchanged for ones that do.

13-25. Prior to starting the machine, inspect the wheel for cracks. A cracked abrasive wheel is likely to fly apart when attaining high speed. Never use a grinder unless it is equipped with wheel guards.

13-26. Before we begin our study of Chapter 4, turn to the workbook and answer exercises for Section 13.

175

Hand and Machine Forming of Metals

FORMING (the key to success or failure of the airframe repairman) is based on many skills which the repairman must master before he is allowed to attach a part to an aircraft. Parts are formed at the factory on large presses or by drop hammers equipped with dies of the correct shapes. Every part is planned by factory engineers. Specifications for the material to be used are set up so that the finished part has the correct temper when it leaves the machines. A layout for each part is prepared by factory draftsmen.

2. Forming processes used on the flight line and in the maintenance shops are almost directly opposite from those of the factory in method or procedure. However, these processes have much in common, and many of the factors and techniques learned in one process can be applied to the other.

3. The prime difference between factory and airframe shop processes is that *you* have the responsibility of deciding the requirements needed to fabricate or replace the part needed. Your judgment, based on experience and appropriate guidelines such as technical orders, is needed in the use of machines, handtools, and material to the best advantage. It follows, then, that you must develop knowledges and skills in the proper care and use of layout tools and measuring devices. You must be able to read and interpret drawings, blueprints, and microfilms with a high degree of accuracy in order to layout, fabricate, and duplicate most of the parts you are required to replace.

4. In this chapter you will study print reading, layout, forming processes, and forming equipment to enable you to produce a better product with less effort. In so doing you will develop knowledges essential in repairing, inspecting, and the supervising of airframe repairs. We begin with a review of layout and measuring tools most important in any airframe repair process.

14. Blueprints

14-1. The presentation of an object by lines of a drawing furnishes the person who is to make it with definite instructions concerning its size and shape. However, it does not give him other necessary information he must have if he is to construct the object as it was intended by the draftsman. This additional information—such as name, number, material from which it is to be fabricated, and other pertinent information—is essential if the object is to be made correctly.

14-2. The draftsman must provide this essential information without adding to the complexity of the drawing; yet, it must be placed so that it will be interpreted correctly. Usually, such information is placed in the title block, the change block, or in notes placed so as not to interfere with the drawing itself. In turn, the airframe repairman/technician must be able to read and interpret drawings, prints, or sketches, and sometimes must construct drawings prior to fabrication or repair. Seldom will you use originals; rather, you will probably use black and white or blueprints.

14-3. **Format.** Printed and bound in the back of this volume is a foldout, which is a reproduction of AF Form 1654. Study it closely as you read the remainder of this information about prints. A blueprint is an economical reproduction of an original scale or working drawing.

14-4. *Title block.* The headlines on the blueprint are in the title block, or box, which is located in the lower right-hand corner of all drawings prepared according to military standards. The title block may appear elsewhere on other blueprints, but the lower right-hand corner is the usual placement.

14-5. The title block contains the drawing number and all the information required to identify the part or the assembly that the blueprint represents. In approved military blueprints, the title block of the drawing includes the name and address of the Government agency that prepared it, title, scale, drafting record, authentication, and date.

14-6. ***Title information.*** The portion of the title block which gives the name of the agency issuing the blueprint and the name and number of the part or assembly is located in the lower right-hand corner of the title block. These items are usually in larger and more prominent letters and figures.

14-7. *Next assembly information.* To the left of the title block there are spaces for the signature of the draftsman, checker, engineer, and the project engineer. Below this there is a space for the contract number and the signature of the authenticating official. Left of this, there is a column for tolerances, material, and the type of finishing required. At the extreme left there are vertical columns in which the application and quantity requirements are normally shown.

14-8. *Drawing numbers.* All drawings are identified by a drawing number which appears in a number block in the lower right-hand corner of the title block. It may be shown in other places—such as near the top border line, in the upper right-hand corner, or on the reverse side of the drawing at both ends—so that the number will show when the drawing is folded or rolled. The purpose of the drawing number is for quick identification of a blueprint. If a blueprint has more than one sheet and each sheet has the same number, this information is included in the number block indicating the sheet number and number of sheets in the series.

14-9. *Reference and dash numbers.* If reference numbers appear in the title block, they refer to the numbers of other blueprints. No reference numbers are shown in the foldout. When more than one detail is shown on a drawing, dash numbers are used. Let us suppose that two parts are shown in one detail drawing. Both would have the same drawing number plus an individual number, such as 40267–1 and 40267–2.

14-10. Dash numbers may be shown in the title block or on the face of the drawing near the parts they identify. Dash numbers are also used to identify right-hand and left-hand parts.

14-11. In aircraft, many parts on the left side are like the corresponding parts on the right side, but in reverse. The left-hand part is always shown in the drawing. The right-hand part is called for in the title block. Above the title block will be found a notation such as: 74204–1LH shown: 74204–2RH opposite. Both parts carry the same number, but the part called for is distinguished by a dash number. Some commerical prints have odd numbers for left-hand parts and even numbers for right-hand parts.

14-12. *Scale.* The scale of the drawing is indicated in one space of the title block. It indicates the size of the drawing as compared with the actual size of the part. The scale is usually shown as 1 inch = 2 inches, 1 inch = 12 inches, etc. It may be indicated as full size, one-half size, one-fourth size, and so forth. If the draftsman has used a scale of 1 inch = 2 inches, the object is shown half as large as its actual size. For a scale of 3 inches = 1 inch, the object is drawn three times its actual size. Very small parts are reduced in size to show views clearly.

14-13. Remember: Never measure a drawing. Use the dimensions given on the blueprint.

14-14. *Heat-treatment.* Most metals require some form of heat-treatment in a manufacturing process. The title block on a blueprint, drawing, or specification lists the type of heat-treatment needed. Frequently it is necessary to remove the temper from a piece of metal so that it can be machined to specifications, after which it is hardened. Reference is usually made to the heat-treatment specification in the title block.

14-15. *Bill of material and specifications.* A special box on the drawing may contain a list of the pieces of stock necessary to make a part or an assembly of several parts. It is called a bill of material and tells the kind of stock, the size, and the specifications.

14-16. Many items (such as bolts, screws, turnbuckles, and rivets) have been standardized by the Army, Navy, and Air Force. Each such item has a number with an AN in front of it. A wing nut, for example, has a specification of AN 350. A flathead sheetmetal screw is listed as AN 531.

14-17. Always use the material specified. The material indicated was selected by an engineer because it meets the requirements of the job it is to do. It is the best material for that particular job. Only an engineer or a person having the authority of an engineer can authorize substitutions of materials when the specified material is not available.

14-18. *Zone numbers.* Zone numbers on blueprints are similar to the numbers and letters printed on the borders of a map. They are there to help you locate a particular point. To find a point, mentally draw horizontal and vertical lines from the letters and numbers specified; the point where these lines would intersect is the area sought.

14-19. Use the same method to locate parts, sections, and views on large blueprints, particularly assembly drawings. Parts numbered in the title block can be located on the drawings by finding the numbers in squares along the lower border. Zone numbers read from right to left.

14-20. *Station numbers.* A numbering system is used on large assemblies for aircraft to locate stations such as fuselage frames. When you see

"Fuselage Frame-Sta 185," you know that the station intended is on the frame 185 inches from nose or intake of the aircraft. The measurement is usually taken from the nose or zero station, but in some instances it may be taken from the firewall.

14-21. The same station numbering system is used for wing and stabilizer frames. The measurement is taken from the center line or zero station station of the aircraft.

14-22. *Finish marks.* Finish marks are used to indicate the surface that must be machine finished. Such finished surfaces must have a better appearance and allow a closer fit with adjoining parts. During the finishing process the required limits and tolerances must be observed. Do not confuse machined finishes with those of paint, enamel, chromium plating, and similar coating.

14-23. Drawings prepared according to Government specifications require a surface roughness symbol. Full explanation for the use of these symbols can be found in the publication, *Military Standard Surface Roughness, Waviness, and Lay.*

14-24. *Tolerances.* When a given dimension on a blueprint shows an allowable variation, the plus figure indicate sthe maximum and the minus figure indicates the minimum allowable variation. The sum of the plus and minus allowance figures is called tolerance. For example, using .225 + .0025 − .0005, the plus and minus figures indicate the part will be acceptable if it is not more than .0025 larger than the .225 given dimension, or not more than .0005 smaller than the .225 dimension. Tolerance in this example is .0030 (.0025 max plus .0005 min).

14-25. If the plus and minus allowances are the same, you will find them presented as .224 ± .0025. The tolerance will then be .0050. Allowance can be indicated in either fractional or decimal form. When accurate dimensions are necessary, decimal allowances are used. Fractional allowances are sufficient when close demensions are not required. Standard tolerances of − .010 or − 1/32 may be given in the title block of many blueprints to apply throughout the drawing.

14-26. *Usage block.* A usage block may be used to identify, by drawing numbers, the larger unit of which the detail part or assembly shown forms a component part. This block is usually near the title block; or it may form a part of the list of the material block.

14-27. *Notes.* There are times when a person who is to make the object illustrated will need additional information that cannot be placed in either the title or change blocks on the blueprint. In such cases, the information is put on the face of the blueprint in a position which does not interfere with the title block, the change block, or the drawing itself. The information is specific and applies to a particular part or parts.

14-28. When the note refers to a specific part, a light line with an arrowhead on its distal end leads from the note to the part. If it applies to more than one part, the note is worked so that the individual reading it will make no mistake as to the parts to which it pertains. When there are several notes, they are generally grouped together and numbered consecutively.

14-29. *Change or revision block.* A revision block is located on the right-hand side of the print. The general practice is to put this space in the upper right-hand corner, but it may be placed above the title if desired. All changes to the drawings are entered in this block and are dated and identified by a number or a letter. If a revision block is not used, a revised drawing may be shown by adding a letter to the original number (for example 140365–21–A).

14-30. **Microfilms and Their Uses.** The practice of recording drawings on microfilms was introduced in recent years. Microfilm is regular 16mm or 35mm film. Since 35mm film is larger, it provides a better reproduction of drawings. Depending on the size of the drawing to be reproduced, a varying number of drawings can be photographed on one reel of 35mm film. To view or read drawings on a reel of film, you need either a portable 35mm projector or a microfilm reader or viewer.

14-31. The advantage of microfilm is that several reels, which duplicate perhaps hundreds of drawings, require only a small amount of storage space. Too, a person working on an aircraft may need to refer to a specific dimension. He can place the reel of microfilm in a projector, locate the drawing, and read the dimension. If he has to study a detail of the drawing, or work with the drawing for a long period of time, an enlarged photographic reproduction can be made, using the microfilm as a negative.

14-32. Microfilms of drawings have many other uses and advantages. However, microfilm is not intended to replace original drawings, especially where the originals are modified and kept current over long periods of time.

14-33. When drawings are filmed on continuous reels, corrections can be made by cutting out superseded drawings and splicing in the revised ones. When these corrections become numerous, the procedure becomes impractical and is discarded in favor of refilming the drawings.

14-34. A method which allows corrections to be made easily and at any time is to film the drawings and then cut up the film into individual frames. These are inserted into transparent protective envelopes, and thus become slides which need to be arranged in sequence so that any desired drawings can be located quickly. The only disadvantage to this method is that it is time consuming.

14-35. A 70mm microfilm has become available recently. With it, larger size drawings can be reproduced as individual frames or slides, and these can be inserted in regular paper envelopes and kept in an ordinary file. When held to the light, this large microfilm can be read with the naked eye.

14-36. Before we continue to the next section, turn to the workbook and answer exercises for Section 14.

15. Drawings

15-1. The exchange of ideas is essential to everyone, regardless of his vocation or position. Usually, this exchange is carried on by the oral or written word; but under some conditions these methods are impractical. Industry discovered that it could not depend entirely upon written or spoken words for the exchange of ideas, because misunderstanding and misinterpretation arose when these methods alone were used. In giving a written description of an object, one can change the entire meaning just by misplacing a comma. Similarly, the meaning of an oral description can be completely changed by the wrong word. To avoid these errors, industry uses drawings to describe objects. For this reason, drawing is called the Draftsman's Language.

15-2. Drawing, as we use it, is a method of conveying ideas concerning the construction or assembly of objects. This is done with the help of lines, notes, abbreviations, and symbols. It is very important that you understand the meaning of the different lines, notes, abbreviations, and symbols used in drawing.

15-3. **Descriptive Terms**. To convey an accurate description of an object by using a drawing, the person describing the object and the one for whom the description is made must use uniform definitions of terms. The following explanations are given to help you understand the terms in this chapter.

15-4. *Length*. A straight line is the shortest distance between two points. Length is the distance between two end points of a line. In plane geometry this term usually refers to the longest dimension of a plane figure lying in the same horizontal plane. For example, figure 53 shows a board, lying in a horizontal plane, to which a cleat has been attached. The length of the board is 24 inches and the cleat is 18 inches

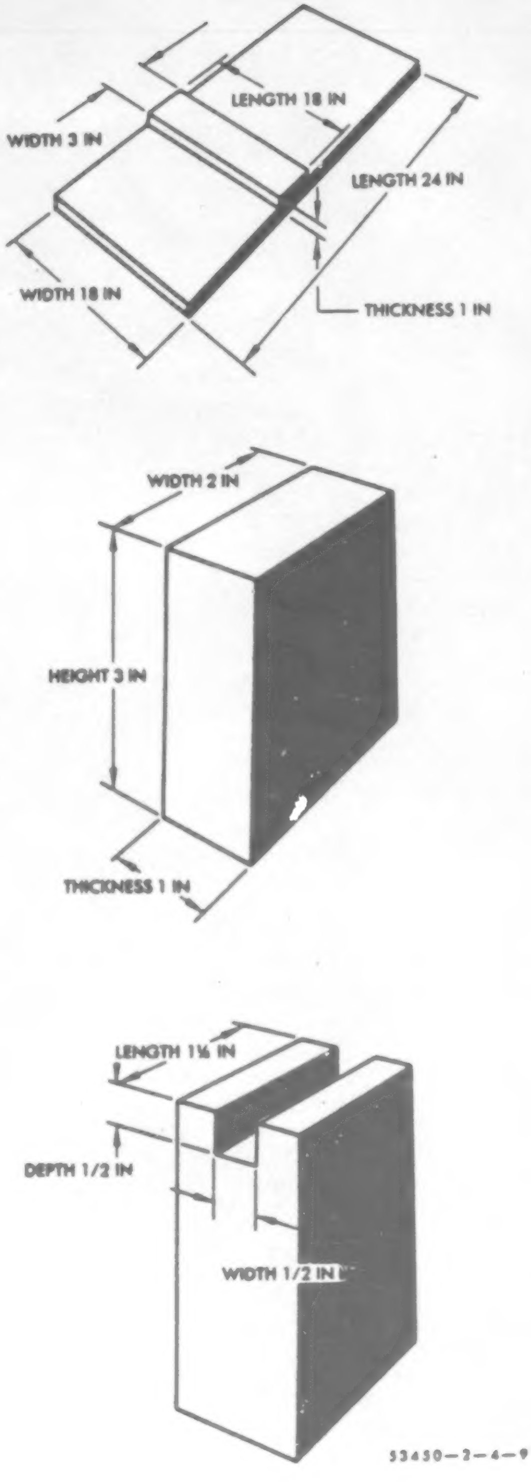


Figure 53. Use of descriptive terms.

in length. In both cases, the length is the greatest dimension lying in the same plane of the object. Dimensions for squares or equal-sided figures are excepted since all sides are equal.

15-5. *Width.* The term width usually refers to the least dimension of a plane surface at right angles to the length and in the same plane. In figure 53 the board is 18 inches in width and the cleat is but 3 inches in width.

15-6. *Thickness.* This term is used for the third dimension of solid objects such as boards or sheets of material. It must be remembered in using this term that it can mean depth and can apply either to the main part of the object or to some separate part attached to the object being described. It can also apply to a part projecting from the object.

15-7. *Height.* This term is used to identify the vertical dimension of a plane figure lying in a vertical plane. It is the shortest distance from the base, or reference point, to another point perpendicular to the reference point. For example, if you place a block upon a table, the height is the distance from the surface of the table to the highest point of the object that is perpendicular to the surface of the table. Instead of referring to this dimension as length, one would refer to it as the height of the block. In figure 53 the block is 3 inches high—that is, its top is 3 inches above its base or above the surface on which it stands.

15-8. *Depth.* Depth, like thickness, is used as a third dimension of a solid measured from the surface viewed to a point or plane away from the viewer such as top to base, front to back. Note in figure 53 the drawing of a block with a groove in the top. We would say this groove is ½ inch in depth, meaning that it extends ½ inch below the top surface of the block.

15-9. **Lines and Their Uses.** Your ability to read this printed page depends upon your skill in recognizing the characters of the alphabet. In addition to recognizing these characters, you must know how they are used in the construction of words and sentences. Likewise, being able to read drawings and blueprints depends upon your ability to recognize the character of the lines used in the making of drawings and to understand how they fit into the description of objects represented. Because of their fundamental importance, these lines are called the alphabet of lines.

15-10. *Visible outlines.* In describing an object with a drawing, the outline of all faces is represented by lines. The surfaces visible to the eye are always outlined in solid lines, which are the most important in the alphabet of lines. Being bold, solid lines, they become the basis for comparison of the weights of all other lines. Notice the weight of this line in figure 54.

15-11. *Invisible outlines.* Surfaces that are invisible, or hidden, are always outlined by using dashed lines, called invisible lines. They consist of a series of short dashes of medium weight, about half as heavy as the lines used to indicate visible surfaces. In the reading of drawings and blueprints, it is important that you remember that a series of short uniform dashes always represents an invisible surface. Examine figure 54 and locate the lines that indicate invisible surfaces. See if you understand why they are not visible surfaces, then compare them with the other lines.

15-12. *Center lines.* For the sake of accuracy in the construction of many objects, it is essential to lay off the dimensions from the center of the object rather than from a face or a side. This is particularly true of circular objects or objects made up of circular curved parts. For this reason, the central axis of such objects or parts must be shown in a drawing. The line used to indicate the central axis of an object is known as a center line. It is a lightweight line made up of a dash approximately ½ inch in length followed by a short dash approximately ⅛ to 1/16 inch in length. Center lines are of about the same weight as invisible lines. Study the center lines shown in figure 54.

15-13. *Dimension lines.* If a drawing is to be satisfactory, it must indicate not only the correct shape but also the size of the object and all of its features. The dimensions and various features are indicated by lines known as dimension lines. These lines may be recognized by the arrowheads on opposite ends of such lines. Dimension lines are solid lines that are lighter than visible outlines. Actually, a dimension line is made up of two parts, because it is not a continuous line. It has a space near the center where a number is inserted which indicates the size of the dimension. Each half of the line has an arrowhead that

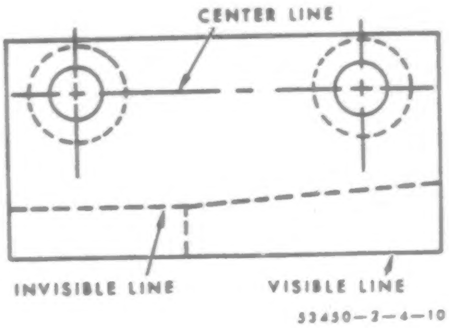


Figure 54. Visible and invisible lines.

indicates the limit of the dimension. (An example of the dimension line is illustrated in figure 76, example B.)

15-14. *Extension lines.* Usually, the draftsman tries to place all dimensions of an object outside of its outline. This is done primarily for neatness and clarity. However. this is not always possible, as many objects have features on more than one surface, making it necessary to place dimensions within the outline. Whether dimensions are placed within or outside the outline of the surface, the limits of the dimensions must be extended out and away from the feature whose dimension is being shown; otherwise the dimension lines will become confusing.

15-15. Lines used to extend the limits of a dimension out and away from the feature itself are called extension lines. Such lines are solid and are lighter in weight than a visible outline line. Usually extension lines are short, particularly when only one dimension is given; but when several dimensions are shown, the lines must be longer. Observe the different extension lines shown in example B of figure 75.

15-16. *Broken material lines.* It is sometimes necessary to indicate on a drawing that a part is broken out or was removed. This is usually done for one of two reasons. It may be to show more clearly the part or parts which lie directly below the part broken out, or it may be to reduce the size of the drawing of a long part so that it may be shown on a smaller drawing. In the latter case, the part broken out is understood to be exactly the same shape as that shown on both sides of the break. When a part is broken out or removed, the break is indicated by irregular solid lines of the same weight as the visible outline lines. These are known as broken material lines. One is shown in figure 55.

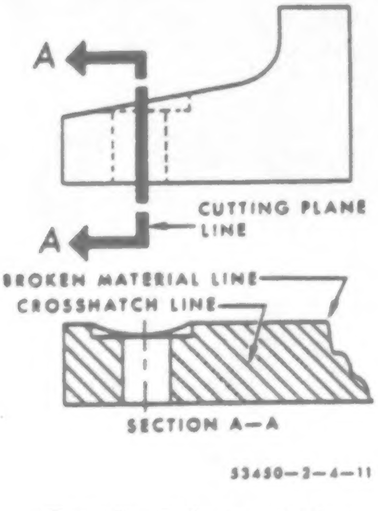


Figure 55. Broken material lines.

15-17. *Cutting plane lines.* In a drawing which describes an object of unusual yet definite shape, it may be necessary to show the exact shape at a particular point on the object. This point is indicated on a drawing by a cutting plane line, which shows that the object has been cut entirely across at that particular point. When such a line is used, a separate drawing representing the cut surface is shown, usually upon the same sheet of paper.

15-18 The cutting plane line is made up of a heavyweight dash followed by two shorter dashes. This line is somewhat heavier than visible lines. At each end it has a short line at right angles to the cutting plane line, tipped with an arrowhead pointing in the direction from which the cut surface is viewed. These lines are labeled with a letter at either end to identify the drawing of the cut surface which is shown with the same letters and is called a section. The cutting plane line and the separate drawing of that surface (labeled section AA) are shown in figure 55.

15-19. *Crosshatch lines.* In drawings it is necessary to indicate that two separate parts meet at a given point. If no distinction were made, a person reading the drawing might assume those parts to be the same piece of material. To distinguish between them, each part is lined or hatched in an opposite direction. Such lines are called hatching or crosshatch lines. They are lightweight solid lines of the same weight as invisible lines. They are placed approximately $\frac{1}{16}$ inch apart and are always parallel. (An example is given in figure 55.) Remember that when two adjacent parts are crosshatched, the lines always run in different directions.

15-20. *Thread depiction.* There are various ways of representing threads on a drawing. Figure 56 indicates how outside threads are shown. At top left you can see a thread profile in section. On the right is an ordinary method of showing threads. To save time, a draftsman uses symbols when objects are not drawn to scale. The length of the threaded part is dimensioned, but other necessary information appears in the note. which in this case is ¼-20-NC-2.

15-21. The first number, ¼, indicates the nominal size, which is the outside diameter. The number 20 after the first dash indicates there are 20 threads per inch. The letters NC indicate the thread series, National Course. (The two most widely used screwthread series are the National Coarse (NC) and National Fine (NF) threads. The NF threads have more threads per inch of screw length than the NC.) The last number, 2 indicates the class of thread and tol-

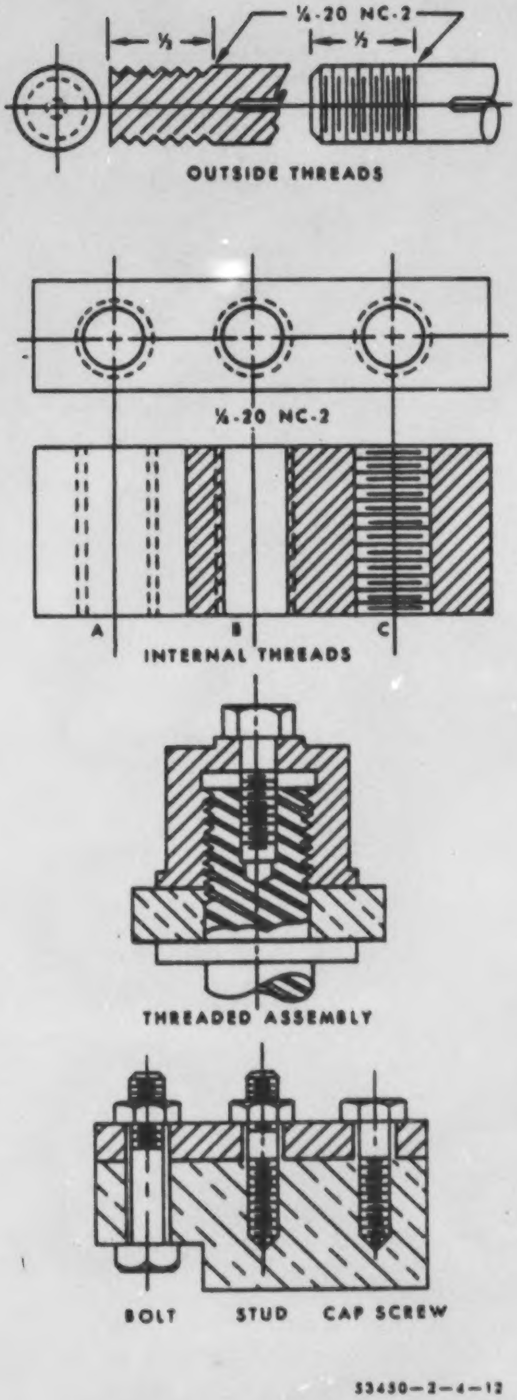


Figure 56. How threads are drawn.

erance, commonly called the fit. If it is a left-hand thread, a dash and the letters LH in bold type will follow the class of thread. Threads without the LH are right-hand threads.

15-22. Internal threads may also be shown by several kinds of symbols. Here, again, it is not necessary to draw the threads when a simple symbol will do just as well. In figure 56, holes A and B will have the same threads as hole C, as indicated by the note. Notice that the threads in the preceding illustration may be screwed into these threaded holes. How do we know? The note on each one tells us that the threads are exactly the same.

15-23. Threads may be shown in section, especially in assembly views. The illustration clearly shows the relationship of the threaded members.

15-24. Bolts, studs, and capscrews are indicated on drawings by outlines and symbols as shown at the bottom of figure 56.

15-25. **Scale and Size.** When possible, drawings are made to the actual size of the object being described. However, it is obvious that many objects are so large that actual size drawings would be impossible to use in a shop. So the draftsman makes the drawings to some fractional part of the true size of the object. He enlarges the drawings of small objects. When a drawing of an object is made to its actual size, it is known as a full size or full scale drawing. If it is drawn to some fractional part of its true size or enlarged, it is called a scale drawing.

15-26. *Scale*. The scale to which a drawing is made is the ratio between the actual size of the drawing and the actual size of the object. The scale used for the drawing should be indicated upon it. This information is usually found in the title block of the drawing (lower right corner of the foldout), but it may be on the face of the drawing itself. The scales most commonly used are full, three-quarter, half, quarter, and one-eighth.

15-27. The scale used is indicated on the drawing in one of many ways. If the drawings are made to the actual size of the object, they are indicated as full scale, and so forth. If drawings are made larger than the actual size of the object, they are indicated as twice full size or twice full scale.

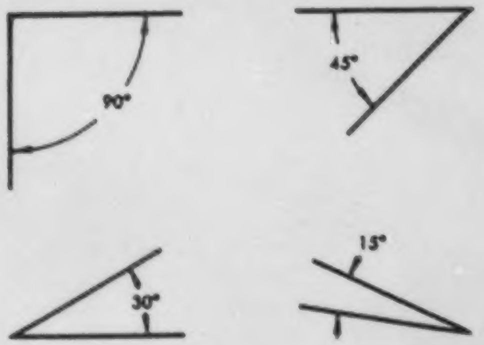
15-28. *Size*. As stated previously, drawings are made full size whenever possible, or as nearly so as can be suitably approached. In large aircraft companies where thousands of blueprints are used and retained for future reference, some thought must be given to their storage and to the prints made from them. Because of this fact, all drawings are made according to a set of standard sizes. Eight and one-half by eleven inches has become the standard size for most small drawings or blueprints. Larger sized drawings are usually made in some multiple of this size, which permits folding to the standard size and storing conveniently.

15-29. In learning to read blueprints, it should be remembered that drawings or blueprints should never be measured (or scaled, as it is often called). Drawings, when complete, should indicate all dimensions, thus making it unnecessary to measure them. A drawing that is incomplete—does not give specific dimensions—should be returned to the drafting or engineering department to be corrected.

15-30. **Dimensioning.** A dimension line is a light, solid line, broken at the midpoint for insertion of measurement indications, and having opposite pointing arrowheads at each end to show origin and termination of a measurement. It is generally parallel to the line for which the dimension is given, and usually placed outside the object and between views if more than one view is shown.

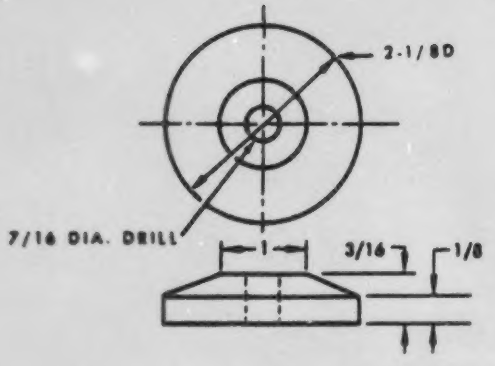
15-31. *Location of lines.* Draftsmen do not always follow it, but there is a standard procedure for placing dimensions on a drawing. Learn this procedure so you can read drawings and blueprints quickly and accurately.

15-32. All dimensions and lettering are placed so that they read from left to right. The dimension of an angle is indicated by placing the degree of the angle in its arc. The dimensions of circular parts are always given in terms of the diameter of the circle and are usually marked with the letter D or the abbreviation DIA following the dimension. The dimension of an arc is given in terms of its radius and is marked with the letter R following the dimension. Parallel dimensions are placed so that the longest dimension is farthest from the outline and the shortest dimension is closest to the outline of the object. On a drawing showing several views, the dimensions are placed to the best advantage to show the details of each view.



53450—2—4—13

Figure 57. Dimensioning angles.



53450—2—4—14

Figure 58. Dimensioning small parts.

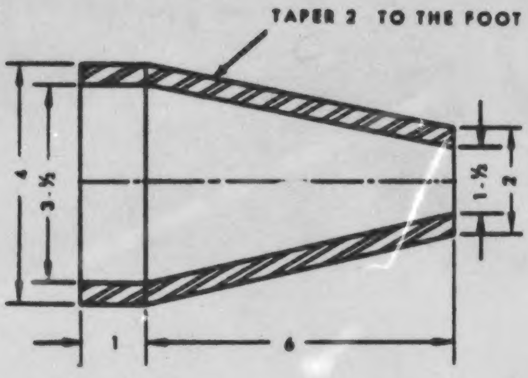
15-33. *Angles.* Angles are dimensioned as shown in figure 57. An arc is drawn and the dimension (degree of the arc) is placed so as to read from a horizontal position. If the angle is too acute to allow space for the dimension, it may be placed as in the example of the 15° angle.

15-34. *Small parts.* In the dimensioning of small parts, the available space is often so limited that it prohibits the use of normal size dimensioning lines, symbols, or figures. In such instances, dimensioning is accomplished by lettering notes or sizes to one side and extending arrows, called leaders, to the small parts. (Study figure 58.) Arrows and figures should always be kept in the clear as much as possible.

15-35. *Tapers.* A dimensioning method for an object having inclined or tapered sides is shown in figure 59. Outside dimensions are placed farthest from the object, and inside dimensions are nearest to it. Taper to the foot means the difference in diameter in 1 foot increments in the length of the object.

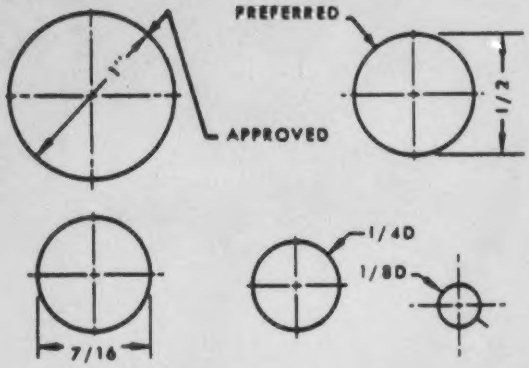
15-36. *Curves.* A curved object may be drawn and dimensioned by using several radii, or by what is known as the offset method. In the offset method, the path of the curve is found by taking a number of measurements from an established line, as AB in figure 60. Dimensions are marked at points indicated by C and at equally spaced points on the object. The distance between the vertical dimensions are given horizontally, as at point D and at similar points.

15-37. *Geometric solids.* In dimensioning spheres, the diameter is given on the view that


TAPER 2 TO THE FOOT
4
3-½
1-½
2
1
6

53450—2—4—13

Figure 59. Dimensioning tapers.


1"
APPROVED
PREFERRED
1-1/2
7/16
1/4D
1/8D

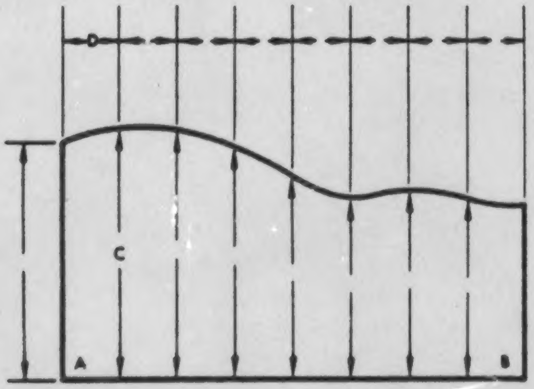
53450—2—4—17

Figure 61. Dimensioning circles.

is most convenient. Ordinarily, only one view of a cone is needed for indicating the diameter and height. The height of a pyramid can be shown on the front view and any other dimensions on a view of the base. The two necessary dimensions of a cylinder, length and diameter, can be shown on one view.

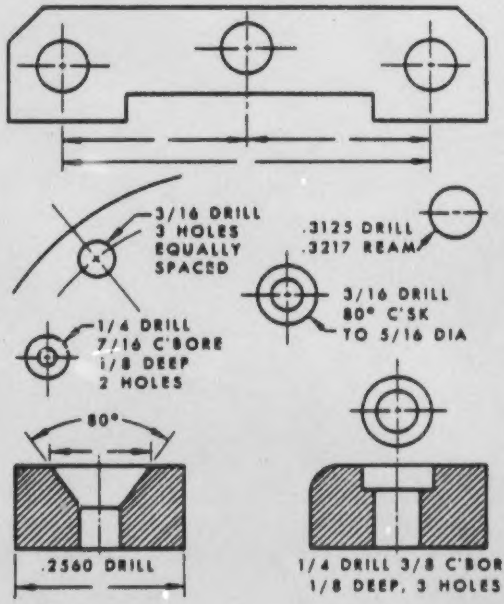
15-38. *Circles.* Diameter dimensions are given for circles, while radius dimensions are given for arcs. Center lines must not be used as dimension lines; therefore, diameters of circles are sometimes shown by lines within the circle. While this method is approved, a preferred practice is to use extension lines and to place the dimensioning outside the circle. (Figure 61 illustrates the correct procedure.) Another way is to show the diameter of a leader at one side with the arrow touching the circumference. This method is better when dimensioning small diameters.

15-39. *Holes.* In dimensioning distances between holes in an object, dimensions are usually given from center to center rather than from outside to outside of the holes. When a number of holes of various sizes are shown, the desired diameters are given on a leader followed by notes indicating the machining operations for each hole. If a part is to have three holes of equal size, equally spaced, this information is given. For precision work, sizes are given in decimals. Diameters and depths are given for counterbore holes. For countersunk holes the angle of countersinking and the diameters are given. Study the examples shown in figure 62.



53450—2—4—16

Figure 60. Dimensioning curves.


3/16 DRILL
3 HOLES
EQUALLY
SPACED
.3125 DRILL
.3217 REAM
3/16 DRILL
80° C'SK
TO 5/16 DIA
1/4 DRILL
7/16 C'BORE
1/8 DEEP
2 HOLES
80°
.2560 DRILL
1/4 DRILL 3/8 C'BORE
1/8 DEEP, 3 HOLES

53450—2—4—18

Figure 62. Dimensioning holes.

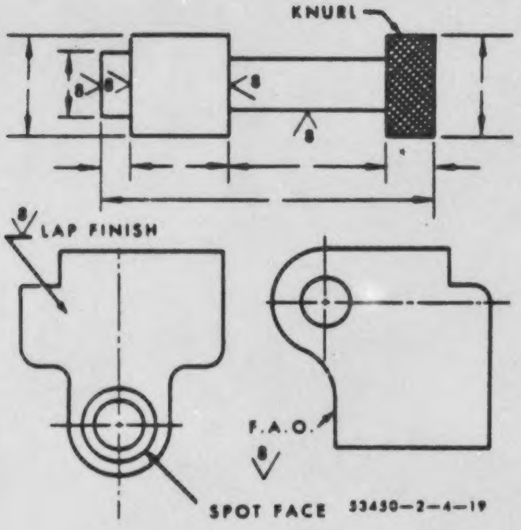


Figure 63. Dimensioning finishes.

15-40. *Finishes.* Dimensions should always give the size of the finished product, regardless of the scale of the drawing. A modified V symbol is used with a number or numbers above it to indicate surface finish. (See fig. 63.) The numbers tell the machinist what degree of finish the surface should have.

15-41. *Assembly and detail dimensioning.* The dimensioning of a complicated machine or a large object may at first appear to be a very difficult task. However, if the object is considered as an assembly of small parts, the task becomes relatively simple. There should be information given as to the position these component parts will occupy in relation to each other. This is done by location dimensioning, which gives the distance from one part to another. Thus, the complete size description of a large object is found to be no more difficult than that of a small one.

15-42. *Tolerance.* Tolerance is the amount of allowable variance from a perfect measurement. It is expressed in decimals, usually in at least three places. There are several ways of indicating tolerance on a drawing. With the unilateral method, the minimum or maximum measurement is used as the dimension figure and the difference allowable is given as a plus or minus tolerance figure, as in example A in figure 64. In the bilateral method (in example B), the dimension figure indicates the plus or minus variation acceptable. In the limit dimensioning method (example C), the maximum and minimum measurements are both given. These are all accepted methods of indicating tolerance on drawings and blueprints.

15-43. *Fits.* The dimensions given for fits signify the amount of clearance allowable between moving parts. A positive allowance is indicated for a part that is to slide or revolve upon another part. A negative allowance is given for a force fit. Whenever possible, the tolerance and allowances for desired fits should conform to those set up in the American Standard for Tolerances, Allowances, and Gages for Metal Fits. The classes of fits specified in the standard may be indicated on assembly drawings.

15-44. *Views.* A photograph of an object gives a good idea of the shape and the relationship of the various parts, and may show the exact size of the object. What then is the value of a photograph compared to a blueprint? A camera brings all visible parts into one picture view on one plane. It records pictures of objects much as your eyes see them. The photograph is deceptive, however, just as your eyes are deceptive.

15-45. Have you ever looked down a straight stretch of railroad track? Your eyes told you that the rails came together at a distant point, but you knew they were parallel. You can't always believe your eyes. The camera, likewise, would record this deceptive appearance. The lines on a photograph do not register the true length and shape. Therefore, photographs cannot be used when accurate blueprints are required.

15-46. Photographic prints are valuable visual aids when used to show the general location, function, and appearance of parts and assemblies. They are often used to show the special characteristics of parts. Operational steps are often shown

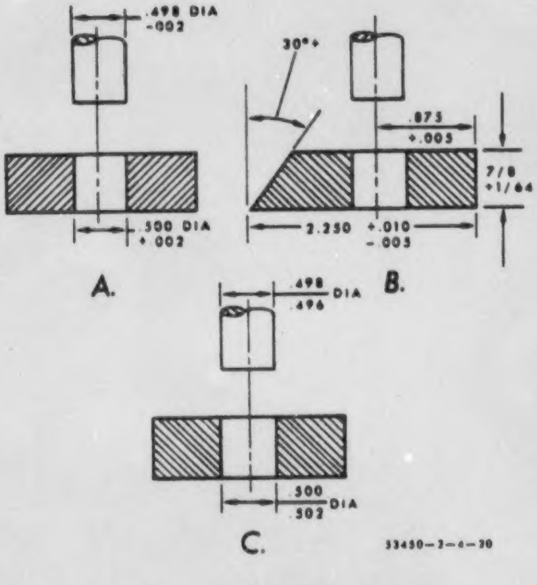
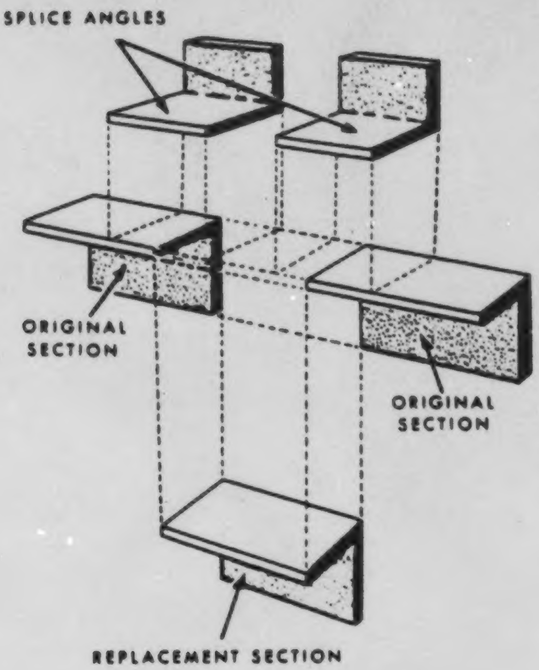
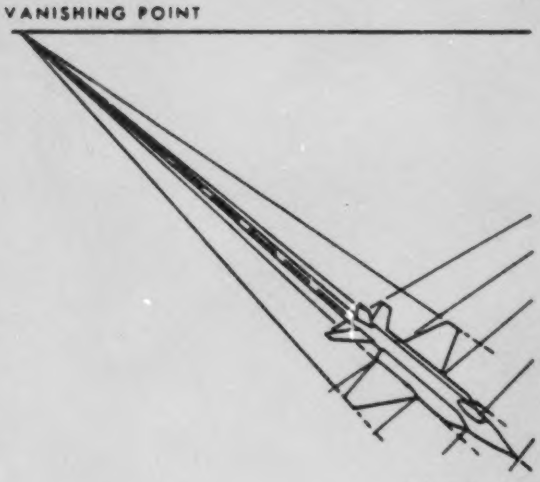


Figure 64. Indicating tolerance.



53450—2—4—21

Figure 65. Exploded views.



53450—2—4—22

Figure 66. Perspective views.

by a series or sequence of photo prints. You can learn to disassemble and reassemble a part or unit by using photographs as a guide.

15-47. *Exploded views.* A valuable use of the photograph is for exploded views that show the location of parts. The illustration of a stringer repair in figure 65 is an example of an exploded view. Notice how the parts are spread out to show clearly each part's relation to the others.

15-48. *Perspective views.* Perspectives are excellent substitutes for photographs and may be used in the same manner. They provide a picture of a new type of aircraft or machine before such an article has been manufactured. The draftsman can creat such drawings.

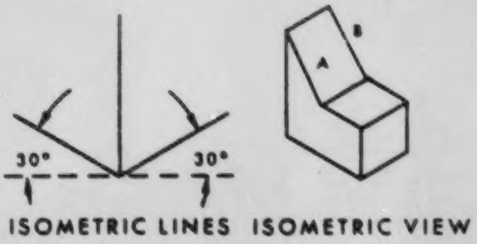
15-49. On a perspective, lines that are actually parallel on the object would run together if extended on the drawing. In figure 66, notice the length of the right and left wings. They are actually the same length, but if measured on the drawing one will be found shorter than the other. Although the perspective provides a picture prior to manufacture, it is not used in the place of blueprints in construction or repair work.

15-50. *Isometric views.* The isometric is somewhat like both the photograph and the perspective. However, on the isometric, lines that are actually parallel on the object would also be parallel on the drawing. All its lines representing horizontal and vertical lines on an object have true length. Vertical lines are shown in a vertical position, but lines representing horizontal lines are drawn at an angle of 30° with the horizontal. Vertical lines and lines representing horizontal lines on such drawings are known as isometric lines.

15-51. In figure 67, all lines except A and B have true lengths because they are vertical and horizontal lines on the object. Lines A and B are not isometric lines and their lengths are not true.

15-52. Isometrics have much the same use as other drawings. In addition, they may be dimensioned so that blueprints of these drawings may be used for making simple objects. But isometrics alone cannot be used for complicated parts or structures.

15-53. *Orthographic views.* Blueprints that furnish complete information for construction and repair present an object in its true proportions. Such prints are copies of mechanically drawn



53450—2—4—23

Figure 67. Isometric view.

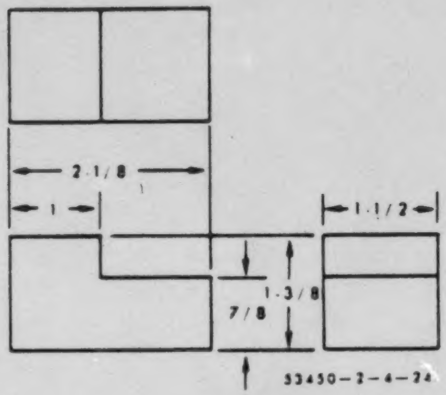


Figure 68. Orthographic view.

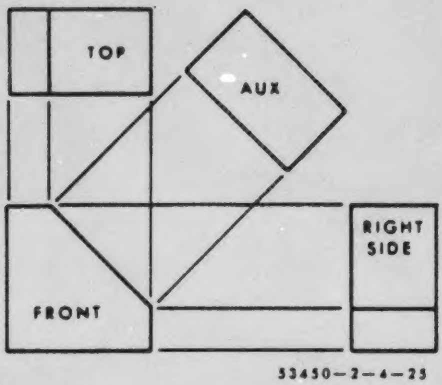


Figure 69. Auxiliary views.

orthographic views. (See fig. 68.) These views are accurate and indicate true shape and size.

15-54. When you study orthographic views, look at one view at a time, to get a good idea of a set of steps, for example, you must look at them from either the right-hand or left-hand side, then from straight in front and behind, and also from the top. By observing several points, you can obtain a clear understanding of the set of steps. This is the basic principle of orthographics.

15-55. You can see a surface of an object in its true shape and size only by looking directly at that surface, as shown in the illustration. Your line of sight must be perpendicular to that surface at all points. When these views of the various surfaces are placed on a drawing, their proper relationship is maintained by the proper arrangement of the views.

15-56. *View arrangement.* Study the arrangement of the three views in figure 68. The side view (lower left) is the starting point. It was selected because it shows the most characteristic feature of the object, the step. The front view is projected directly to the right of the side view. Some of the lines on the front view lie along extensions of lines of the side view. Notice that the top view is placed directly above the side view and that some of its lines lie along extensions of lines of the side view.

15-57. After you study each view, try to visualize the appearance of the object. Think of the object as being immovable, and pretend that you are moving around it. This should help you to relate the blueprint's view to the appearance of the object concerned.

15-58. *Auxiliary projection.* Look directly at the front view in figure 69. Notice the inclined surface and how it appears foreshortened rather than its true size. Now look at the right side and top views. They are true size. For a condition like this, the draftsman uses a special helping view known as an auxiliary. It is obtained by looking directly at the inclined surface. This orthographic auxiliary provides a reliable view of an inclined surface.

15-59. *Curved surfaces.* Curved surfaces do not always look curved in an orthographic drawing. This is because you are looking at the top, bottom, or side of an object at 90° to the surface —looking directly at it. You often see curved edges which indicate a curved surface behind them; and when you see the surface itself in another view, you see it broadside and it appears flat.

15-60. The example illustrated in figure 70 is a two-view orthographic drawing of a cone. You know that the side of a cone is curved, but you cannot see the curvature in example B. You can see the bottom edge of this curved side in example A, so you know that it does exist. It is a good idea to keep in mind that curves in orthographic drawings do not show curved surfaces but may indicate a curved surface behind them. It is up to you to find that surface on one of the other views.

15-61. **Types of Drawings.** Note in figure 71 the two different types of drawings of a block.

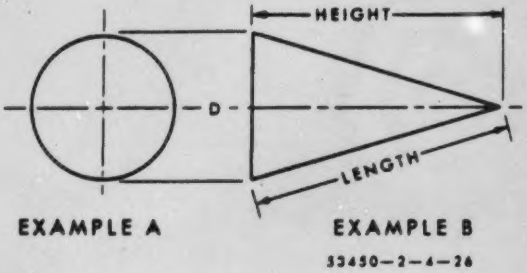
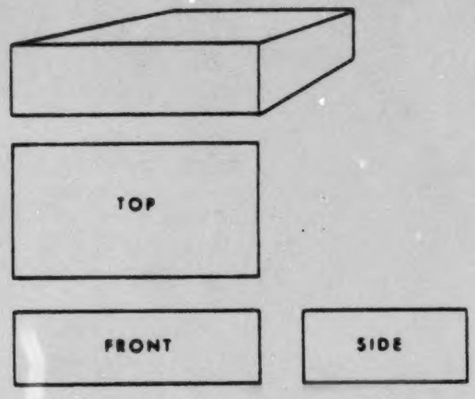


Figure 70. Solid cone.



53450-2-4-27

Figure 71. Pictorial and projection drawing.

The illustration in the top of the figure is a pictorial drawing, so called because it is similar to the picture of a block. The other views in the bottom of the illustration are called projection drawings because they are projections of the same block.

15-62. Pictorial drawings are used only to a limited extent, even though they are more easily understood by those not accustomed to reading drawings. Projection drawings, although more difficult to read and understand, are used almost exclusively to describe objects to be made by workmen.

15-63. Pictorial drawings have a distinct disadvantage as they show the features of an object in a somewhat distorted way. Projection drawings, on the other hand, have the advantage of showing all the features in their true shape.

15-64. In comparing the two drawings of the block, note that in the top view we see the front, top, and one side of the block connected so that the drawing closely resembles a picture of a block, while in the other view we see the front, top, and side definitely outlined, but not directly connected. In the top view it appears that the angles at the four corners of the front, top, and side of the block are not equal, while in the other view we find that all angles are equal.

15-65. *Projection drawings.* A projection drawing of an object shows one principal face and one or more adjoining faces. These adjoining faces are not connected directly above or to the left or right.

15-66. Often, lightweight solid lines are used to almost connect the adjoining faces with the principal face; but they should not acutally connect. These lines, called projection lines, are used to locate the position of the same point on an adjoining face or faces. In a projection drawing, each face is represented as though you were looking directly at that face. The outline of the face as represented on the drawing is called a view.

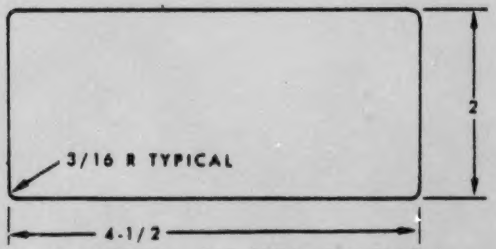
15-67. In most projection drawings it is necessary to show at least two faces or two views of the object. This is done to show the three main dimensions—length, width, and thickness. The view showing the front or principal face is called the front view. It shows that part of the object which would be seen if you were standing directly in front of the object and looking squarely at it. The front view shows two dimensions, the length running from left to right, and the thickness running from top to bottom.

15-68. In order to show the remaining dimension, width, at least one additional view must be shown. This dimension, the distance from the front face to the back face of the object, may be shown in either the top or side view.

15-69. If the draftsman desires to show this dimension in the top view, he merely places the top view directly above the front view. This view then shows the shape and dimensions of the top face as seen by standing directly in front of and looking down upon the top face of the object. This top view shows the distance from the front edge to the back edge of the top, or its width, and also the length which would be shown in the front view.

15-70. To show width in a side view, the draftsman makes a side or end view directly to the right or left of the front view. This view shows the shape and dimension of the side or end face as seen when looking directly at that face. The side view will show the distance from the front to the back face of an object and the same thickness dimension as shown in a front view.

15-71. *Single-view drawings.* In making drawings of objects to be constructed, a great deal of time and labor can be saved by making only one view of the object, omitting the other two views entirely. The information ordinarily given



MATERIAL .040 2024—T ALCLAD

53450-2-4-28

Figure 72. Reinforcement plate.

on the second and third views is usually given in notes accompanying a single-view drawing.

15-72. Look at figure 72, which illustrates a one-view drawing of a reinforcement plate. The plate is to be made of sheet stock, and other views would only show the thickness of the stock (0.040) in addition to the length and width which are given in the single view shown. To attempt to show this thickness, the lines representing the two faces would be so close together they would appear as one line. Since a note stating the thickness of the material can be made, it is placed on the single-view drawing.

15-73. Single-view drawings are used only for objects made of thin material, such as sheet stock, and only when they are perfectly flat, never when they are bent or curved.

15-74. *Surface drawings.* The face of any solid object is called a surface, and the limits of any surface on a drawing are indicated by means of lines. A surface has two dimensions, length and width. It does not have thickness. When it is necessary to indicate an edge view of a surface, a line is used. Even though the line has thickness, the surface itself does not.

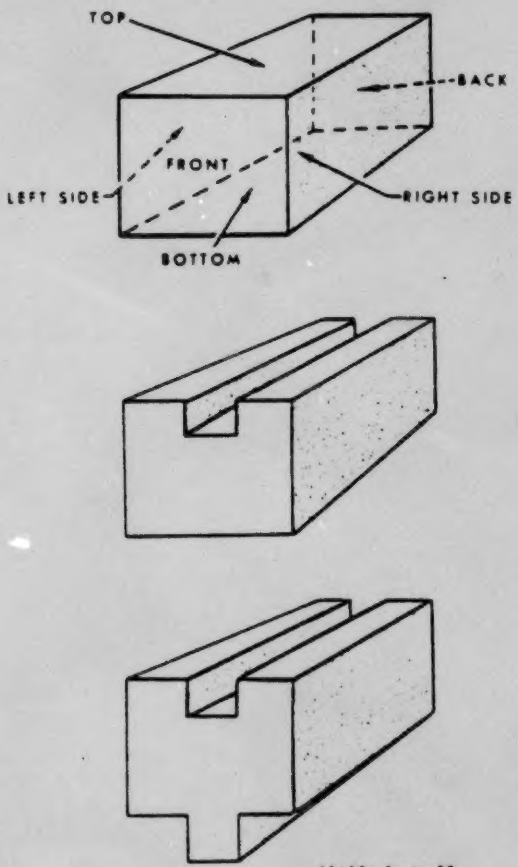


Figure 73. Surface drawing.

15-75. *Number of surfaces.* Study the object illustrated in the first of the illustrations on figure 73. We can determine that it has six surfaces. These surfaces are usually called the front, back, top, bottom, right side, and left side.

15-76. Now study the second illustration. We can recognize the same object with a groove cut in the top surface. If we count its surfaces, we can determine that there are 10.

15-77. Examine the third illustration. We find the same object, except that a projection is shown on the bottom. Count the surfaces and we find there are now 14.

15-78. It is easy to see from the study of these illustrations that the number of surfaces upon an object can be increased or decreased by changing the shape of one or more of its surfaces.

15-79. *Number of views.* It was stated earlier that a projection drawing consists of the principal face of an object and one or more adjoining faces. It was also pointed out that in order to show the three dimensions, it is usually necessary to show at least two views.

15-80. Many times it is desirable to make a drawing of three views of an object. This is necessary when it has special features that cannot be shown in two views with sufficient completeness to enable a repairman to construct the object without additional information. For this reason, projection drawings consisting of three views are used. These views are usually the front, top, and either the right or left side views.

15-81. Another method used in drawings is that of representing features of an object in a view which cannot actually be seen in that view. Such features are indicated by means of dotted lines. This brings to our attention the first rule for the reading of drawings and blueprints: *Solid lines always represent the outline of features which are visible, and lines composed of small uniform dashes always indicate the features which are invisible.*

15-82. *Six surfaces on three views.* Figure 74 illustrates the six surfaces of a plain object by showing a view for each surface. Such a drawing, obviously, requires more time, labor, and a larger piece of paper.

15-83. For these reasons, a drawing usually presents the six surfaces by three views. This can be done very satisfactorily if the draftsman adheres to the rule which identifies the outline of visible features with solid lines, and of invisible features with dotted lines. If you keep the following facts in mind, you will more readily understand such drawings:

a. The back surface of an object lies directly behind the front surface, and it is customary to represent on the front view all features which are upon the front surface and all features which lie behind the front surface. Features which are back of the front surface are shown by dotted lines to indicate that they are not visible. However, if a feature which is invisible lies directly back of a visible feature, the two are represented by a soild line.

b. In the same manner, the bottom surface lies directly below the top surface of an object, and it is customary to represent all features which appear upon the bottom surface with dotted lines in the top view, indicating that they are invisible.

c. It should be remembered in describing any surface that the person making the description is looking at the center of that surface. As in the top and bottom views and the front and back views, the right-side view lies directly back of the left-side view or vice versa. In making either side view, the features which are not visible on the surface being described but which lie back of it, are shown by dotted lines to indicate that they are not visible.

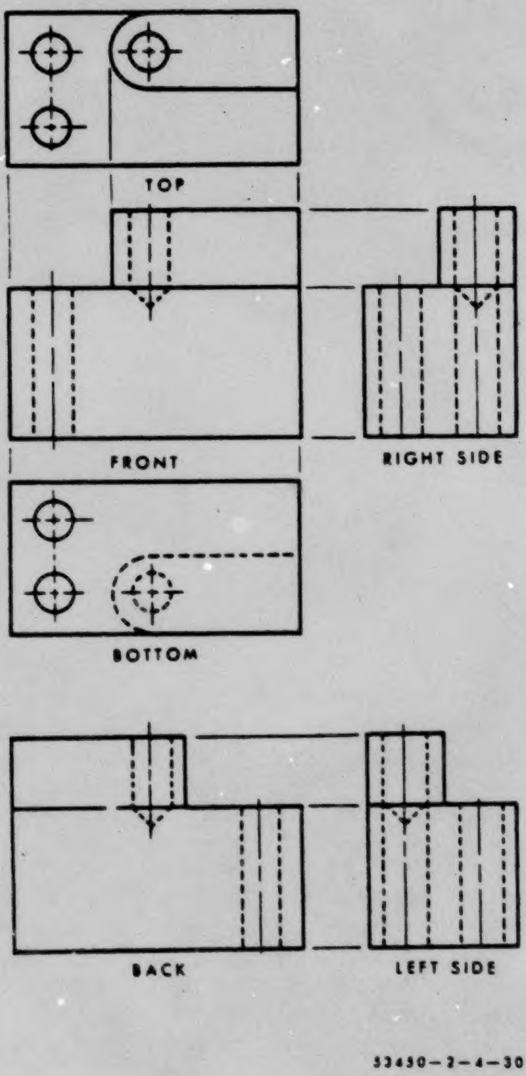


Figure 74. How surfaces are shown.

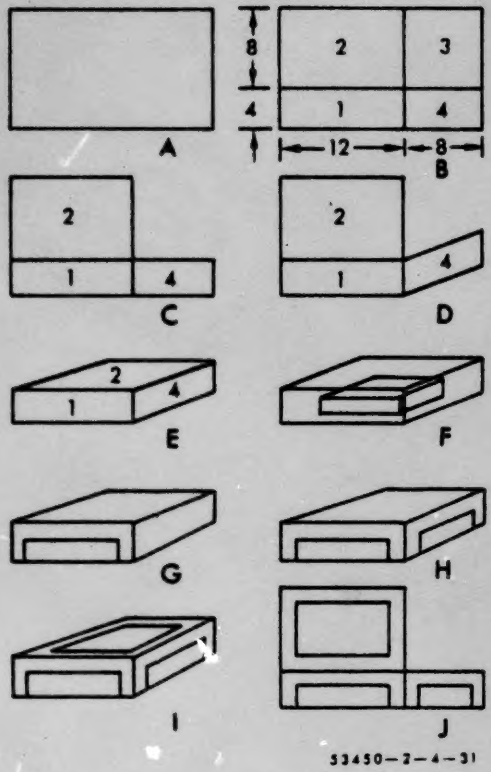


Figure 75. Interrelation of views.

d. By remembering the above facts, and that an edge of any surface is represented by a line, it can easily be seen that objects with many surfaces may be represented on a three-view drawing without difficuity or confusion.

15-84. *Interrelation of views.* In addition to knowing that six surfaces can be shown in three views, an individual learning to read blueprints should also understand the correlation of these three views. An understanding of this can be developed by studying a series of examples with explanations.

15-85. In figure 75, example A shows a piece of plastic 12 by 20 inches in size. Example B shows four rectangles marked off on the plastic. The size and number of the rectangles are given. Example C shows that rectangle 3 has been cut

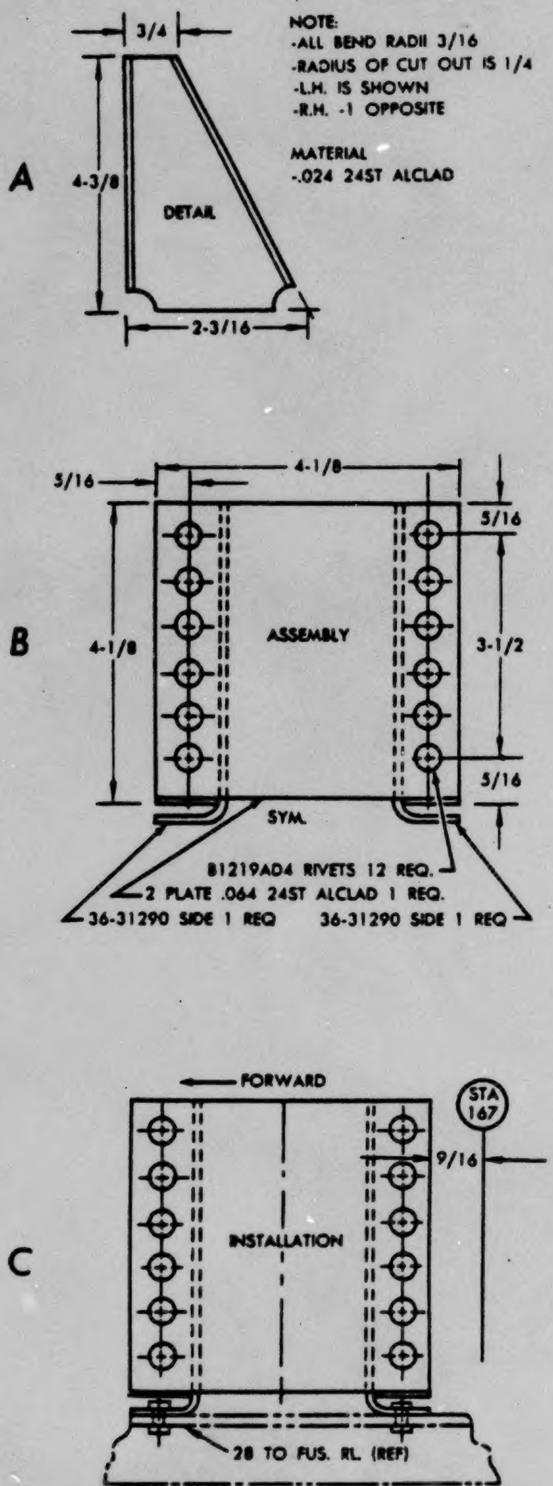

A
3/4
NOTE:
-ALL BEND RADII 3/16
-RADIUS OF CUT OUT IS 1/4
-L.H. IS SHOWN
-R.H. -1 OPPOSITE
MATERIAL
-.024 24ST ALCLAD
4-3/8
DETAIL
2-3/16
B
5/16
4-1/8
5/16
4-1/8
ASSEMBLY
3-1/2
5/16
SYM.
81219AD4 RIVETS 12 REQ.
2 PLATE .064 24ST ALCLAD 1 REQ.
36-31290 SIDE 1 REQ
36-31290 SIDE 1 REQ
C
FORWARD
STA 167
9/16
INSTALLATION
28 TO FUS. RL. (REF)

Figure 76. Working drawings.

out and removed from the original piece of plastic. Example D illustrates that rectangle 4 has been bent back to form a right angle with rectangle 1. Example E shows that rectangle 2 has also been bent back to form a right angle with rectangle 1. Example F illustrates that a block has been placed under the plastic form so that the front side and end of the block are approximately 2 inches from rectangles 1 and 4 and that the front side of the block is parallel to rectangle 1.

15-86. In example. G, the outline of the front side of the block has been drawn on the plastic, in pencil, in rectangle 1. Example H shows the outline of the end of the block drawn in rectangle 4, in addition to the front outline in rectangle 1. Example I shows the outline of the top of the block, in pencil, upon the plastic in rectangle 2, in addition to the outlines in rectangles 1 and 4. Example J illustrates that the plastic has been bent back into its original flat shape.

15-87. This shows the relation of the three views of the block and how they were obtained. This same relation always exists in three-view drawings which show front, top, and right-side views.

15-88. *Working drawings.* It was pointed out previously that most drawings are of the projection type; however, some aircraft companies also use pictorial drawings. This is an additional help for the workman in visualizing the objects represented in the pictorial drawings. In such cases, the pictorial drawings do not give full and complete information concerning the object represented. Instead, they present a representation of the shape and arrangement of the parts of a certain object. Figure 76 illustrates a working drawing. Essential information which a person must have in order to make or assemble an object is given on a projection drawing. Such information is necessary to make or assemble the object represented. It is known as a working drawing.

15-89. Working drawings must give such information as size of the object and all its parts, its shape and that of all of its parts, specifications as to the material to be used, how the material is to be finished, how the parts are to be assembled, and any other information essential to making and assembling the particular object.

15-90. Working drawings are usually divided into three classes: detail drawings, assembly drawings, and installation drawings.

15-91. *Detail drawings.* A detail drawing is a description of a single part, describing by lines, notes, and symbols the size, shape, material, and methods of manufacture that are to be used in making or assembling the object. Detail drawings are usually rather simple; and, when single parts are small, several detail drawings can be shown on the same sheet or blueprint. Figure 76 (top) shows a detail drawing within a working drawing.

15-92. *Assembly drawing.* An assembly drawing is a description of an object made up of two or more parts. Examine the assembly drawing in figure 76. It describes the object by giving, in a general way, the size and shape. Its primary purpose is to show the relationship of the various parts. An assembly drawing is usually more complex than a detail drawing, and is often accompanied by detail drawings of various parts.

15-93. *Installation drawing.* An installation drawing (as shown in fig. 76) is one which includes all necessary information for a part or an assembly of parts in the final position in the aircraft. It shows the dimensions necessary for the location of specific parts with relation to the other parts, and reference dimensions which are helpful for later work in the shop.

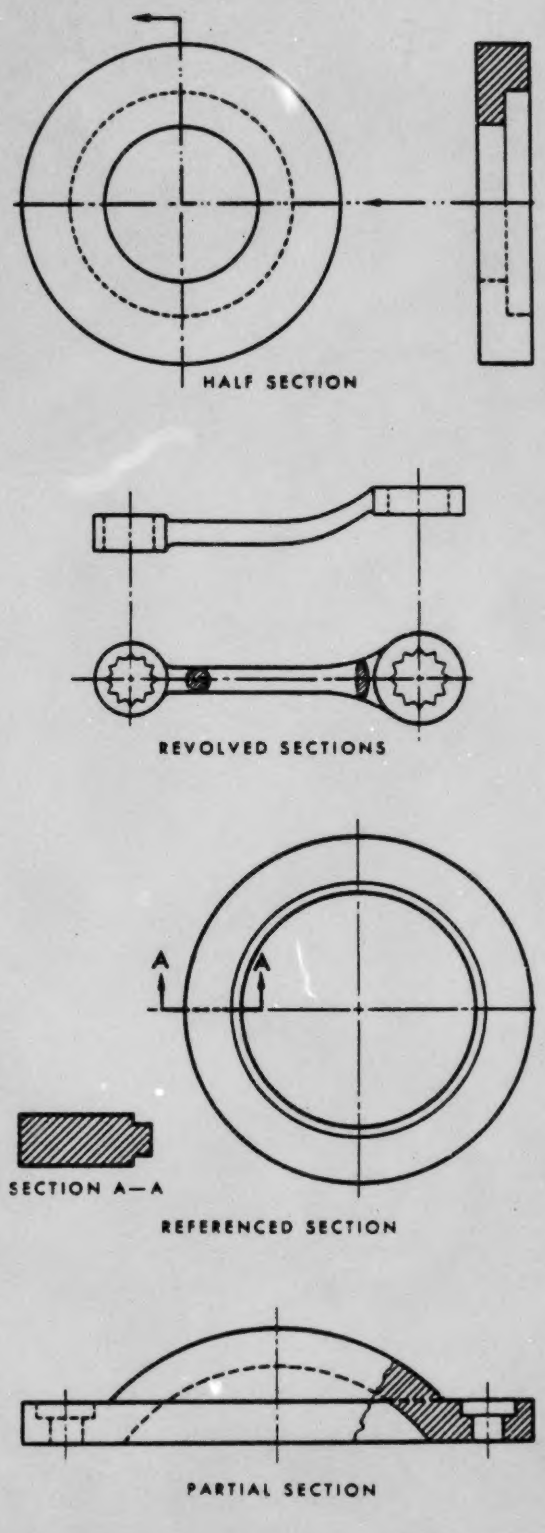
15-94. *Sectional drawings.* We have been dealing with the reading of working drawings that mainly represent the outside views of an object. Information concerning the interior construction of these objects is represented by dotted lines. Dotted lines are adequate for simple drawings, but with more complex drawings it is often difficult to obtain an accurate idea of the interior construction by using only dotted lines. Therefore, draftsmen have developed a method of describing the interior construction of objects by sectional drawings made with solid lines.

15-95. A sectional view is based upon the assumption that the object has been partially cut or broken away, and the part in front of the break has been removed, thus exposing a view of the interior construction at that point. The new exposed surface is shaded by a series of crosshatch lines.

15-96. When a sectional view is made through a solid object such as a nut, bolt, shaft, rivet, or similar part whose axis lies in the cutting plane, the solid part is not crosshatched.

15-97. *Kinds of sectional views.* Sectional views as shown in figure 55 are known as full sections; that is, the object is represented as being cut entirely through. At times it is necessary to represent an object as if it were cut only halfway across. The remaining portion would be shown as a regular view. Such a sectional view is called a half section. This type view is used particularly in describing a symmetrical object in which both halves of a full section would be like.

15-98. In presenting a sectional view of an object, some view, other than the sectional view,



HALF SECTION

REVOLVED SECTIONS

SECTION A—A

REFERENCED SECTION

PARTIAL SECTION

53450-2-4-33

Figure 77. Sectional views.

should include a special line called a cutting plane line which indicates the position of the intended cut. Usually this line has arrowheads pointing in the direction in which the section is viewed, as indicated in figure 77.

15-99. Another type of section used quite extensively is the revolved section. This type is used when it is difficult to represent the true shape of a part at a certain point. The revolved section represents the shape of the object, at a particular point, upon the regular view.

15-100. When it is not possible or convenient to place a revolved section on a drawing in the usual manner, it is placed at any convenient spot on the drawing and is labeled to correspond to the cutting plane line. This type of section is known as a reference or labeled section. (See fig. 77.)

15-101. Partial sections are used when it is not desirable to make a complete sectional view. In these instances, the details of the construction may be shown by a section drawn on the object at the position where it is desirable, as is shown in figure 77.

15-102. Now turn to the workbook and answer the exercises for Section 15.

16. Layout and Measuring Devices

16-1. Layout and measuring devices are precision tools you use in everyday work. They are carefully machined, accurately marked, and, in many cases, are made up of very delicate parts. When you are using these tools, be careful not to drop, bend, or scratch them. The job you do will be no more accurate than the measurements you take or the layout you make; therefore, it is of utmost importance that you understand how to read, use, and care for these tools.

16-2. **Rule.** Rules provided for your use are made of steel and are either rigid or flexible. The flexible steel rule should not be bent intentionally, as it may be broken easily.

16-3. In aircraft metalwork the unit of measure most commonly used is the inch. The inch may be divided into smaller parts by means of either common or decimal fraction divisions. The fractional divisions for an inch are found by dividing the inch into equal parts—halves (½), quarters (¼), eighths (⅛), sixteenths (1/16), thirty-seconds (1/32), and sixty-fourths (1/64)—as shown in figure 78.

16-4. Fractions of an inch may be expressed in decimals, called decimal equivalents of an inch; for example, ⅛ inch is expressed as 0.125 (one hundred twenty-five one-thousandths of an inch).

16-5. Rules are manufactured in two basic types: (1) those divided or marked in common fractions (fig. 78) and (2) those divided or marked in decimals or divisions of one one-hundredths of an inch.

16-6. A rule may be used either as a measuring tool or as a straightedge. To measure a piece of stock, place the rule flat across the surface or distance to be measured, holding or steadying the work. To measure the length of a line, lay the rule alongside the line, with the end of the rule at one end of the line, and read the graduation of the rule that is opposite the other end of the line.

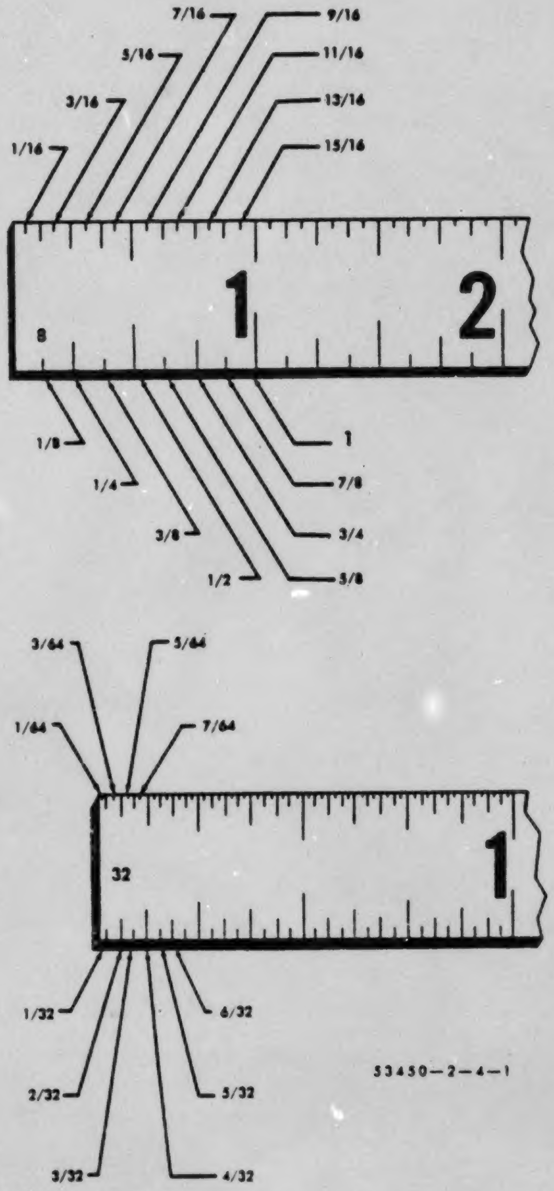


Figure 78. Rule.

16-7. **T-Square.** The T-square most often used has the head securely fastened to the blade. T-squares are commonly made of wood and plastic. (See fig. 79.) The head of the T-square is placed at the left edge of the workbench (for a right-handed worker) and held firmly while drawing. This places the blade of the T-square in a horizontal position. Horizontal lines are drawn along the upper edge of the blade. Vertical or sloping lines are made with the aid of triangles.

16-8. **Triangles.** Triangles are made of plastic, wood, or metal. The most commonly used triangles are the 30°–60° triangle and the 45° triangle as illustrated in figure 79. They are available in various sizes. An 8- to 10-inch 30°–60° triangle and an 8-inch 45° triangle are suitable for most uses.

16-9. Vertical and sloping lines are drawn by use of triangles. The base of the triangle should rest on the edge of the blade of the T-square, and both should be held with the left hand (if you are right-handed), leaving the right hand free to draw the desired line. Start the pencil at a point near the blade of the T-square and proceed upward with the pencil inclined in the direction the line is to be drawn.

16-10. **Dividers and Pencil Compasses.** Dividers and pencil compasses have two legs joined at the top by a pivot. They are used to scribe circles and arcs and for transferring measurements from the rule to the work.

16-11. Pencil compasses have one leg tapered to a needlepoint; the other leg has a pencil or pencil lead inserted. Dividers have both legs tapered to needlepoints.

16-12. In using pencil compasses or dividers, observe the following procedures:

a. Inspect the points to make sure they are sharp.

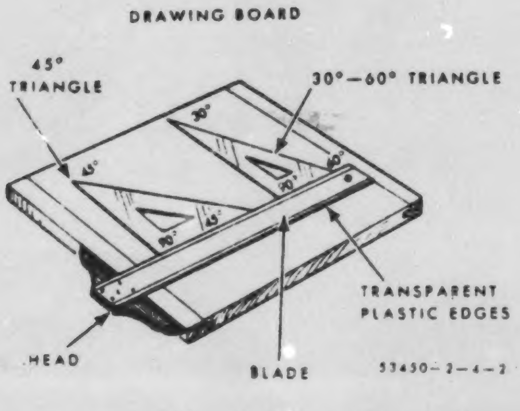

DRAWING BOARD
45° TRIANGLE
30°—60° TRIANGLE
30°
45°
60°
90°
45°
90°
TRANSPARENT PLASTIC EDGES
HEAD
BLADE
53450-2-4-2

Figure 79. T-square and triangles.

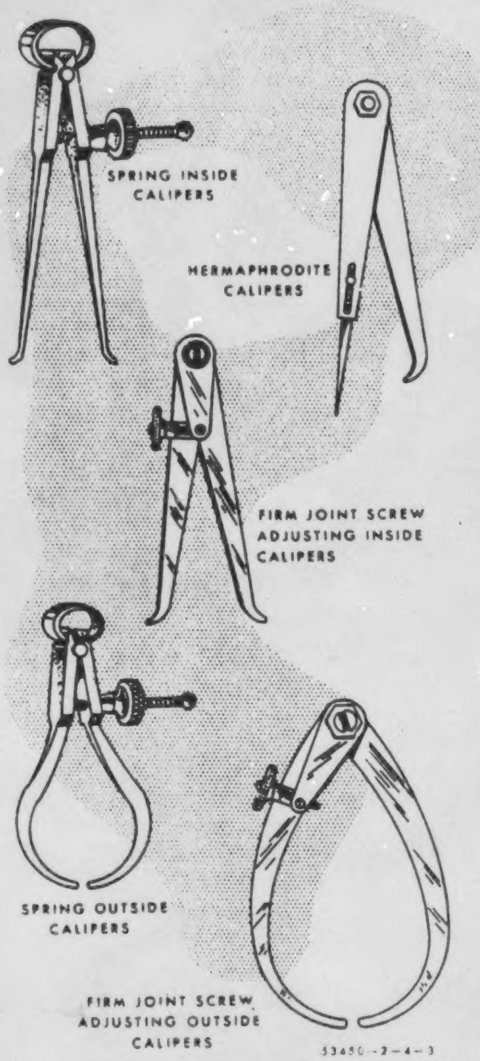

SPRING INSIDE CALIPERS
HERMAPHRODITE CALIPERS
FIRM JOINT SCREW ADJUSTING INSIDE CALIPERS
SPRING OUTSIDE CALIPERS
FIRM JOINT SCREW ADJUSTING OUTSIDE CALIPERS
53450-2-4-3

Figure 80. Calipers.

b. To set the dividers or compasses, hold them with the point of one leg in the graduations on the rule. Turn the adjustment nut with the thumb and forefinger; adjust the dividers or compasses until the point of the other leg rests on the graduation of the rule which gives the required measurement.

c. To draw an arc or circle with either the pencil compasses or dividers, hold the thumb attachment on the top with the thumb and forefinger.

d. With pressure exerted on both legs, swing in a clockwise direction and draw the desired arc or circle.

16-13. The tendency for the legs to slip is avoided by inclining the compasses or dividers in the direction in which they are being rotated. In working on metals, the dividers are used only to scribe arcs or circles that are later removed by cutting. All other arcs or circles are drawn with pencil compasses to avoid scratching the material.

16-14. On paper layouts, the pencil compasses are used for describing arcs and circles. Measurements should be transferred with dividers because they are more accurate.

16-15. **Calipers.** Calipers are used for measuring diameters and distances or for comparing distances and sizes. The three common types of calipers are the inside, the outside, and the hermaphrodite calipers, as shown in figure 80. There are also a number of special types of calipers, such as gear-tool calipers.

16-16. Outside calipers are used for measuring outside dimensions—for example, the diameter of a piece of round stock. Inside calipers have outward curved legs for measuring inside diameters, such as diameters of holes, the distance between two surfaces, the width of slots, and other similar jobs. Hermaphrodite calipers are generally used as marking gages in layout work. They should not be used for precision measurement.

16-17. **Micrometer Calipers.** There are four types of micrometer calipers, each designed for a specific use. The four types are (1) outside micrometer, (2) inside micrometer, (3) depth micrometer, and (4) thread micrometer.

16-18. The outside micrometer illustrated in figure 81 is used by the airframe repairman more often than any other type. It may be used to measure the outside dimensions of shafts, thickness of sheet stock and metal, diameter of drills, and for many other applications.

16-19. All four types of micrometers are read in the same way. The smallest measurement which can be made with the use of the steel rule is one sixty-fourth of an inch in common fractions, and one one-hundredth of an inch in decimal fractions. To measure more closely than this (in thousandths and ten-thousandths of an inch), a micrometer is used. If a dimension given in a common fraction is to be measured with the micrometer, the fraction must be converted to its decimal equivalent.

16-20. The decimal system is a method of expressing fractions and mixed numbers. For example, 2.000 inches written decimally indicate 2 inches. All figures to the left of the decimal point are whole numbers; all figures to the right of it indicate parts of whole numbers. Starting from the decimal point and moving to the right, the first digit indicates tenths; the second, hundredths; the third, thousandths; the fourth, ten-thousandths; and so on. Thus, 2.3 is read two and three tenths; 2.35 is read two and thirty-five hundredths; 0.2351 is read twenty-three hundred and fifty-one ten-thousandths. (When there is no number to the left of the decimal point, the quantity is less than one.)

16-21. *Parts of a micrometer.* The fixed parts of a micrometer, as illustrated in figure 81, are the frame, barrel, and anvil. The movable parts of a micrometer are the thimble and spindle. The thimble rotates the spindle which moves in the threaded portion inside the barrel. Turning the thimble provides an opening between the anvil

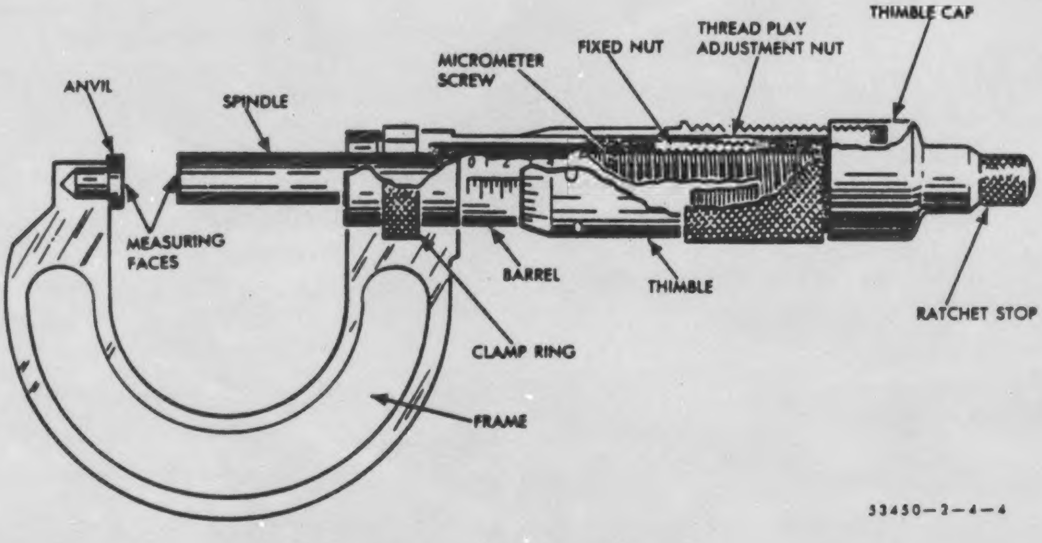


Figure 81. Outside micrometer.

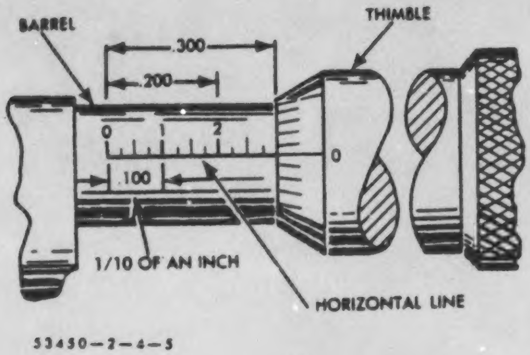


Figure 82. Micrometer barrel.

and the end of the spindle where the work is measured. The size of the work is indicated by the graduations on the barrel and thimble.

16-22. *Reading a micrometer.* The lines on the barrel marked 1, 2, 3, etc., indicate measurements of tenths, or 0.100 inch, 0.200 inch, or 0.300 inch respectively, as illustrated in figure 82.

16-23. Each of the sections between the tenths divisions (between 1, 2, 3, 4, etc.) is divided into four parts of 0.025 inch each. One complete revolution of the thimble (from zero on the thimble around to the same zero) moves it one of these divisions (0.025 inch) along the barrel.

16-24. The bevel edge of the thimble is divided into 25 equal parts. Each of these parts represents one twenty-fifth of the distance the thimble travels along the barrel in moving from one of the 0.025-inch divisions to another. Thus, each division on the thimble represents one one-thousandth (0.001) of an inch. These divisions are marked for convenience at every five spaces by 0, 5, 10, 15, and 20. When 25 of these graduations have passed the horizontal line on the barrel, the spindle (having made one revolution) has moved 0.025 inch.

16-25. The micrometer is read by first noting the last visible figure on the horizontal line on the barrel representing tenths of an inch. Add to this the amount represented by the visible graduations on the barrel between the thimble and the previously noted number. (This is found by multiplying the number of graduations by 0.025 inch.) Add to this the number of divisions on the bevel edge of the thimble coinciding with the line of the graduation. Add all three figures together. The total equals the measurement. (Figure 83 shows several sample readings.)

16-26. *Vernier scale.* Some micrometers are equipped with a vernier scale which makes it possible to read directly the fraction of a division that may be indicated on the thimble scale.

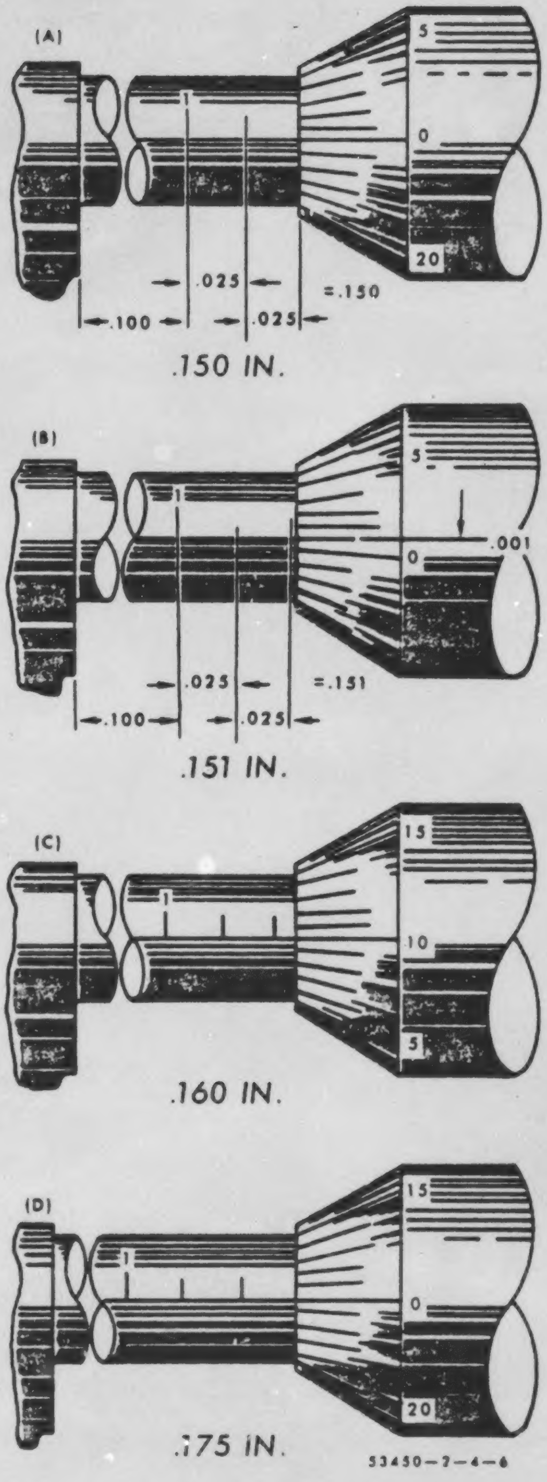
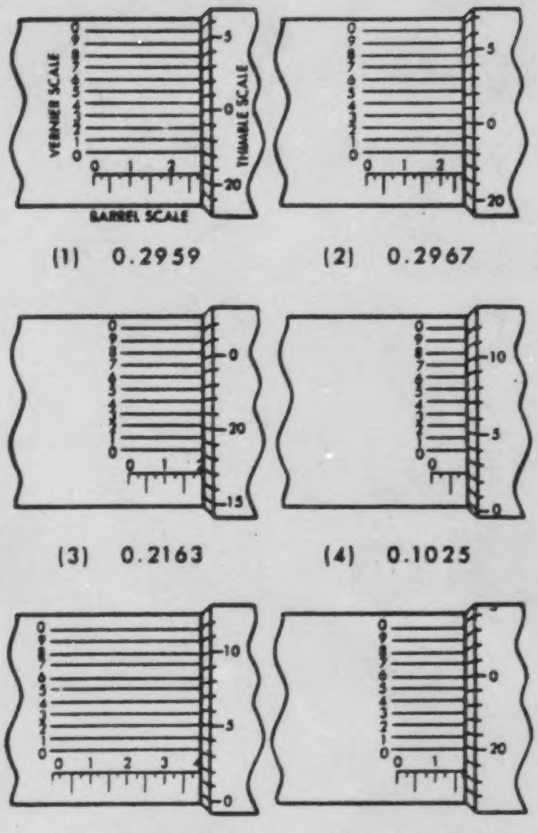


Figure 83. Sample readings.



(1) 0.2959 (2) 0.2967

(3) 0.2163 (4) 0.1025

(5) 0.4019 (6) 0.1936

53450—2—4—7

Figure 84. Vernier scale.

Typical examples of the vernier scale as it applies to the micrometer are illustrated in figure 84.

16-27. All three scales on a micrometer are not fully visible without turning the micrometer, but the examples shown in figure 84 are drawn as though the barrel and thimble of the micrometers were laid out flat so that all three scales can be seen at the same time. The barrel scale is the lower horizontal scale, the thimble scale is vertical on the right, and the long horizontal lines (0 through 9) make up the vernier scale.

16-28. In reading a micrometer, an excellent way to remember the relative scale values is to remember that the 0.025-inch barrel scale graduations are established by the lead screw. Next, the thimble graduations divide the 0.025 inch into 25 parts, each equal to 0.001 inch; then the vernier graduations divide the 0.001 inch into 10 equal parts, each equal to 0.0001 inch. This is the routine to follow: Remembering the values of the various scale graduations, note the barrel scale reading; then add the thimble scale reading to it; then to get the final scale reading add the vernier scale reading. The vernier scale line to be read is always the one aligned exactly with any thimble graduation.

16-29. In the first example in figure 84, the barrel reads 0.275 inch and the thimble reads more than 0.020 and less than 0.021 inch. On the vernier scale, the number 9 coincides with a line on the thimble. To obtain the final reading, we added the barrel reading (0.275 inch), the thimble reading (0.020 inch), and the vernier scale reading (0.0009 inch). So, the final reading is 0.2959 inch.

16-30. In the second example in figure 84, the barrel reads slightly beyond 0.021 inch. On the vernier scale, the number 7 coincides with a line on the thimble. This means that the thimble reading plus the vernier would be 0.0217 inch. Adding this to the barrel reading of 0.275 inch would give us a total of 0.2967 inch.

16-31. The third, fourth, fifth, and sixth examples in figure 84 are additional readings that would require use of the vernier scale for accurate readings to ten-thousandths of an inch.

16-32. *Using a micrometer.* The micrometer must be handled carefully. If it is dropped, its accuracy may be permanently affected. Continually sliding work between the anvil and spindle may wear the surfaces. If the spindle is tightened too much, the frame may be sprung permanently and inaccurate readings will result.

16-33. To measure a piece of work with the micrometer when the work is held in the hand, hold the frame of the micrometer in the palm of the right hand by the little finger or third finger, whichever is more convenient, allowing the thumb and forefinger to be free to revolve the thimble for adjustment.

16-34. **Combination Set.** The combination set illustrated in figure 85, as its name implies, is a tool that has several uses. It can be used for the same purpose as an ordinary tri-square. It differs from the tri-square in that the head can be made to slide along the blade and clamp at any desired place. Combined with the square or stock head are a level and miter. The head slides in a central groove on the blade. The scale or blade can be used separately as a rule.

16-35. The spirit level in the stock head makes it convenient to square a piece of material with a surface and at the same time tell whether one or the other is plumb or level. The head alone can be used as a simple level.

16-36. The combination of square head and blade can also be used as a marking gage, to scribe lines at a 45° angle, as a depth gage, or as a height gage. A convenient scriber is held frictionally in the head by a small brass bushing.

16-37. The center head is used to find the center of shafting or other cylindrical work. The protractor head can be set to draw lines at any angle from 0° to 180°.

16-38. **Irregular Curve.** The irregular curve, also called the French curve, is used to draw smooth irregular curves. To use this tool, the direction of the line to be drawn must be planned and indicated by fixed points. Then these points, taken three at a time, are aligned with the edge of the French curve that will contact all three points. French curves are made in a variety of shapes and sizes and are usually manufactured from a transparent plastic.

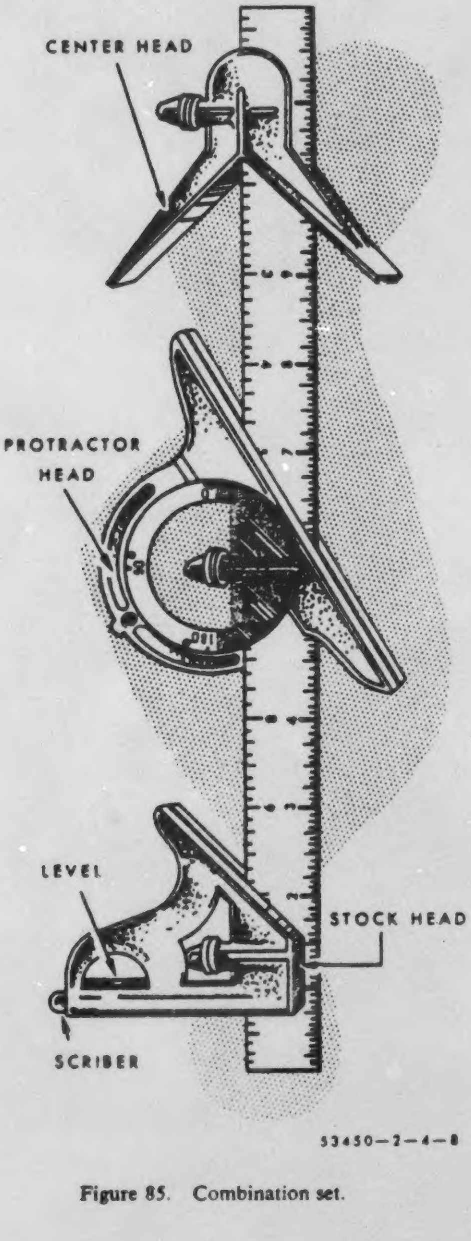


Figure 85. Combination set.

16-39. Now turn to the workbook and answer exercises for Section 16 before proceeding with your study of Section 17.

17. Methods of Pattern Development

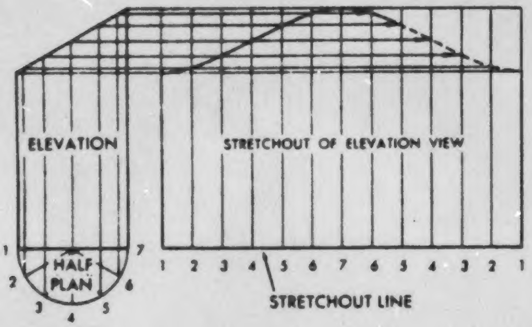
17-1. Occasionally in your work you may have to design ducts and pipes which meet other ducts or pipes at various angles, such as a round air duct joining a square one. By mathematical calculations and drafting methods, you have to determine the size, shape, and curve of the cuts, which when laid out on a flat pattern or blank piece of sheet stock, formed, and put together, will give the correct shape of the object. The edge of the round duct that attaches to the square duct is not a straight line when drawn on a flat-sheet, but is a flowing curve. It ascends gradually to a peak, and then descends gradually on the opposite side. Should the blank be cut out along this curved line and rolled up, it would fit snugly against the elliptical hole in the square duct. The repairman makes such sketches on paper first—that is, he makes layouts or patterns—then he cuts them out and fits them together before he tries them on sheet stock.

17-2. The process by which the repairman projects and drafts lines and curves into layouts is called development. Such airframe drafting is based on those principles of geometry which relate to the surface of solids. Sheet metal articles are hollow and, in airframe drafting, they are considered as if they were coverings for solids of the same shapes.

17-3. The three commonly used methods of development are parallel line development, radial line development, and triangulation. These three methods can be used to develop objects with single curvatures only. Articles such as wing fillets and cowling parts have compound curvatures—that is, bulges which curve in at least two directions at the same time and require stretching and shrinking. They are undevelopable. Their size and form must be determined by trial and error or by slitting the old part open and flattening it out.

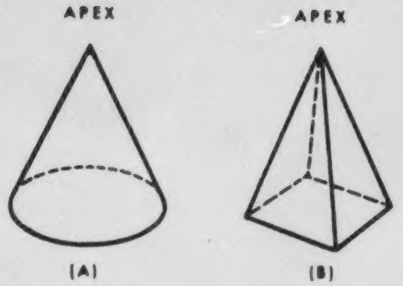
17-4. **Parallel Line Development.** Parallel line development is applicable to forms such as pipes, ducts, T-joints, and the like, which have opposite sides parallel. Whenever laying out patterns for a cylindrical object, consider the object as a form having an infinite number of sides, each of the same length as the form but very narrow.

17-5. During this process of development, first draw an elevation view to show the true length of the sides of the object; next, draw a plan view



53450—2—4—34

Figure 86. Parallel line development.



53450—2—4—35

Figure 87. Objects developed by radial line development.

or a half plan view to show the true size and shape of the end of the object. (In figure 86, a half plan view is shown.) Strike off equal distances along the curved line of the half plan dividing the area around the cylinder into equal parts. The greater the number of parts, the more nearly accurate the layout.

17-6. Now draw a stretchout line, which is the pattern of the part to be formed. This is drawn from the base of the elevation view as illustrated in figure 86. On this line, locate and number the equal spaces laid out on the half plan view. You will have the other half of the cylinder to form too, so locate and number the spaces in the pattern from 1 up to 7 and then back to 1 again. Through these points, draw measuring lines at right angles to the stretchout line. Also, from the points 2 to 6 laid out in the half plan, draw lines to the top line in the elevation view. Draw all these lines perpendicular to the base line.

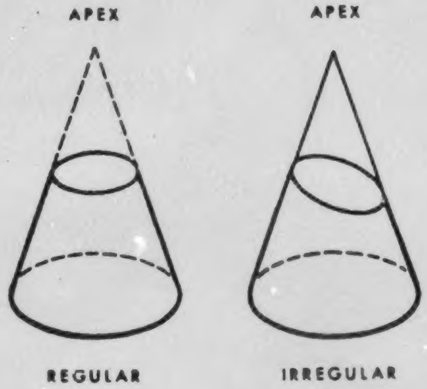
17-7. Next, draw projection lines parallel to the stretchout line and through the points where the vertical lines from the half plan view intersect the top line of the elevation view. Mark the points where these projection lines intersect the correspondingly numbered measuring lines; then connect all these points with an easy-flowing curved line. This curve forms the top angular edge of the pattern; the stretchout line forms the base of the object.

17-8. **Radial Line Development.** Several objects have shapes that will not permit the use of parallel line development because their sides are not parallel. Such forms require other methods of development. Radial line development is one such method; and, as in parallel line development, the objects to be developed must have certain characteristics. Only forms having a circle for their bases, or a base that can be inscribed in a circle, and sides that slant to a common center, can be developed by this method. The center must be located directly over the center of the base. This base, however, may be projected or imaginary rather than the actual base of the object.

17-9. When the base is round, the object has a conical shape (see example A in fig. 87). When the object has a square base, it has the shape of a pyramid (see example B of fig. 87). Any part or section of these cones or pyramids can be developed by radial line development.

17-10. A cone with the top cut off parallel with the base is called a regular frustum. One with the top cut off on an angle with the base is called an irregular frustum (see fig. 88). Objects which have these characteristics can be developed by the radial line methods.

17-11. When you draw a frustum, you locate the apex by extending the sides until they intersect. This point of intersection of imaginary lines is the apex. The apex must be located, regardless of the shape, in order to obtain the slant height.



53450—2—4—36

Figure 88. Truncated cones.

17-12. Generally, the pattern of these objects is fan-shaped. When the object is unrolled, the stretchout pivots around the apex or the pattern radiate from the apex. (See fig. 89.)

17-13. The pattern for a cone is found by using the elevation view and plan view. In this type of line development the elevation has two heights, the actual and the slant. The actual height is used only to draw the elevation view, and the slant height is used as the radius for the stretchout arc.

17-14. The length of the stretchout arc is equal to the distance around the base or plan view. The slant height is the distance from the apex to the base down the visible slant. Note in figure 90 the pattern of an object whose base is not round. However, the radius and the length of the stretchout arc are found in the same manner as if the base of the object were round.

17-15. An irregular frustum presents a slightly different situation, the difference being that the pattern line A–B (in fig. 91) could not be shown as an arc. Therefore, to pinpoint it on the pattern, surface element lines must be constructed on the elevation view. The plan or half plan is divided into equal spaces and then extended up, perpendicular to the base line. From there all surface element lines converge to one point, the apex (fig. 91).

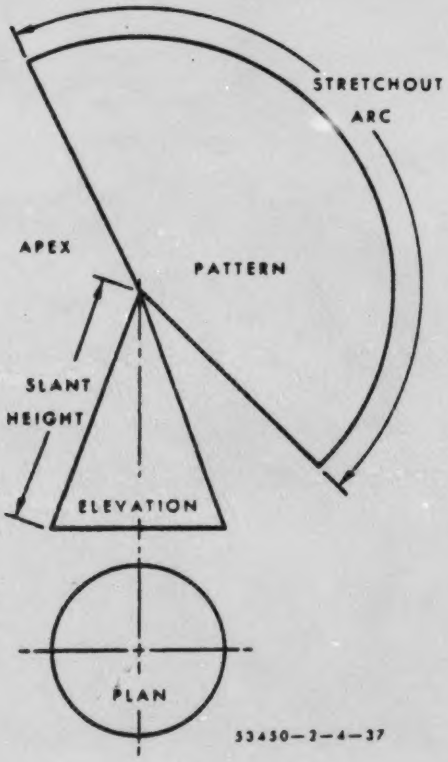


Figure 89. Cone stretchout.

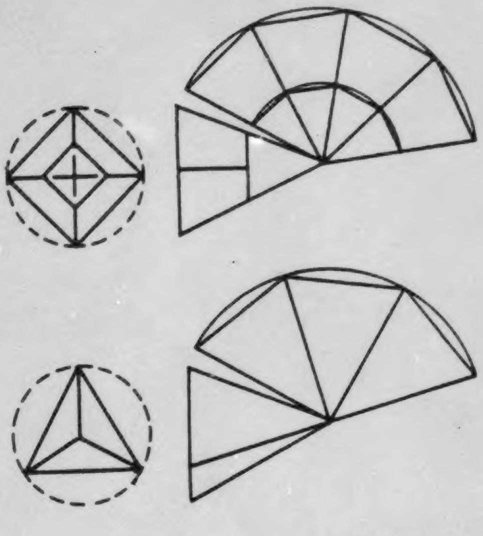


Figure 90. Patterns for objects without round bottoms.

17-16. In parallel line development, the surface element lines are perpendicular to the base; but in radial line development, they are not perpendicular to the base line. These lines are on a slant and therefore are shortened. The only lines that are in their true length are the slant height lines.

17-17. In order to find the true length of all surface lines, simply project them from the line A–B (miter line) to the slant height, as shown in figure 91. All true lengths are taken along the slant height side.

17-18. To develop the pattern shown in figure 91, swing the stretchout arc, using the slant height as the radius. After you find the length of the arc by measuring the distance around the base of the object, divide the arc into surface element lines corresponding to those in the elevation view and transfer the measurement to the lines having the same number as in the pattern. After locating all points, connect them with a curved line to form the outline of the pattern.

17-19. *Layout of half plan view:*

a. Swing half circle equal to the diameter of the base.

b. Divide half plan view into equal parts with dividers.

c. Extend surface element lines upward to base line.

17-20. *Layout of elevation view:*

a. Draw elevation view.

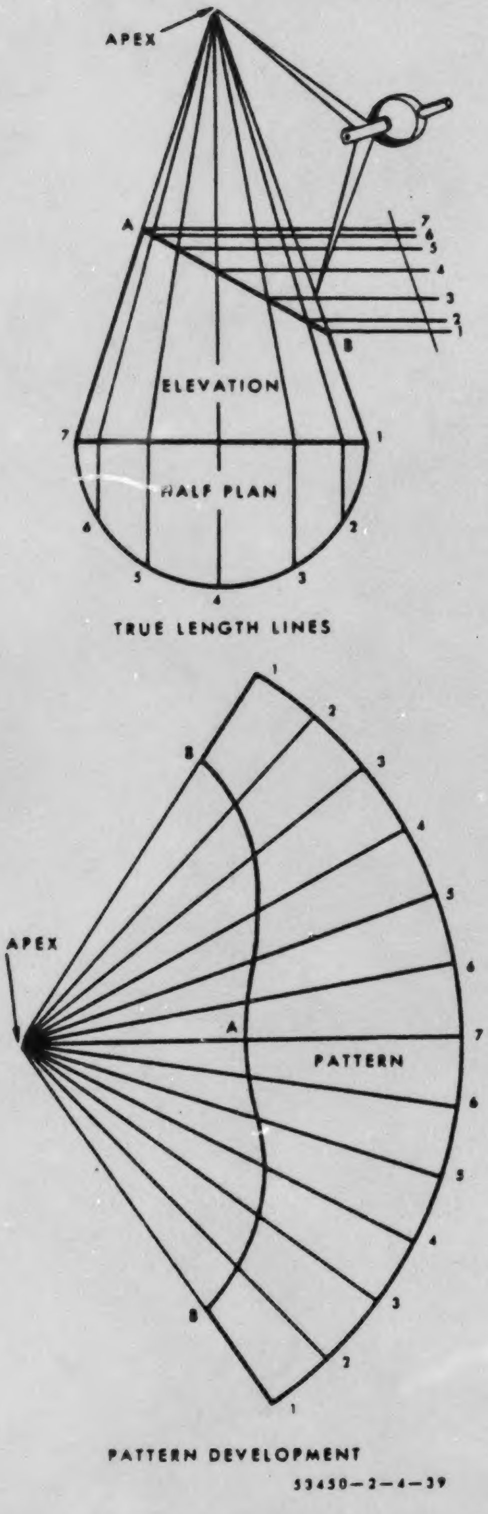

APEX
A
B
7
6
5
4
3
2
1
ELEVATION
HALF PLAN
TRUE LENGTH LINES
APEX
PATTERN
PATTERN DEVELOPMENT
53450—2—4—39

Figure 91. Irregular frustrum development.

b. Extend sides up to center line to obtain the apex.

c. Extend all surface element lines from the base line to the apex.

d. Construct true length if the object is an irregular frustum. (If the object is a regular frustum or cone, no true lengths are necessary; the slant height is then used.)

e. The true lengths are constructed by projecting lines parallel to the base line from the points of intersection of the surface element lines and the miter line over to the slant height.

f. Letter and number all points of importance on the layout.

17-21. *Layout of pattern:*

a. Use the distance along the slant height from the apex to the base line and swing the stretchout arc.

b. Set dividers to the equal space between surface element lines on circumference of half plan view.

c. Mark off equal spaces on the length of the stretchout arc.

d. Extend the surface element lines from the stretchout arc to the apex.

e. Transfer the true lengths of the surface element lines from the elevation view to the pat-

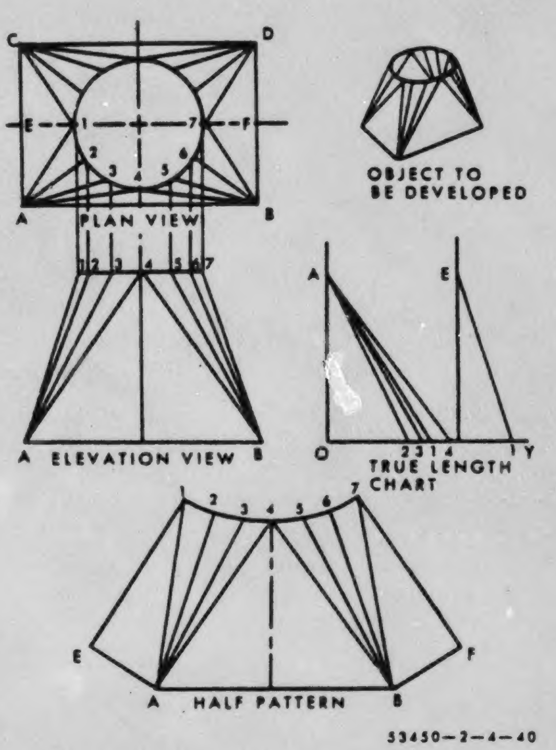

C
D
E
F
1
2
3
4
5
6
7
A
B
PLAN VIEW
OBJECT TO BE DEVELOPED
A
E
ELEVATION VIEW
O
2 3 1 4
Y
TRUE LENGTH CHART
HALF PATTERN
53450—2—4—40

Figure 92. Development by triangulation.

tern, measuring from the apex down the slant height to the numbered true length lines drawn out from the miter line. (If the object is a regular frustum or cone, no true lengths are needed.)

f. Draw the curve and add seam allowance to the ends of the pattern.

17-22. **Triangulation.** The process of triangulation is used for the layout of irregular forms having sides that are not parallel and which, if extended, would not meet at a common point. Forms of this type cannot be developed by methods other than triangulation. Triangulation is applicable to a wide range of layout problems, and, though more detailed than other methods, it is very simple and easy to use when the underlying principles are understood.

17-23. Follow figure 92 as you study step-by-step procedures for the development of a pattern by triangulation.

a. Draw the elevation view of the object.

b. Draw the plan view of the object.

c. Divide the circle in the plan view into a convenient number of parts. Number each point.

d. Draw lines to each of the corners A, B, C, and D.

NOTE: Since lines A–1, A–2, A–3, and so on are foreshortened lines, it is necessary to determine their true lengths before they can be used in the layout of the pattern. This can be done by the use of a true length chart.

e. Construct a true length chart by first drawing line AO perpendicular to a base line OY. Transfer the distances A–1, A–2, A–3, and A–4 in the plan view to the base line OY. Each distance must begin at point O. Now draw lines to these points from point A, thus producing the true lengths of the lines. (Since this object is symmetrical, the following combinations of lines are the same length: A–4 and B–4, A–3 and B–5, A–2 and B–6, A–1 and B–7.)

f. Lay out the half pattern (refer to fig. 92) as follows:

(1) Lay out base line AB.

(2) Locate point 4 by scribing arcs using radii equal to the true length of lines A–4 and B–4. Draw lines A–4 and B–4 on the pattern.

(3) Set your dividers to length 3–4 on the plan view. Using this measurement, scribe arcs to the right and left of point 4 on the pattern.

(4) From pattern points A and B, respectively, scribe arcs having radii equal to the true length of lines A–3 and B–5 to intersect the previously made arcs. Draw lines A–3 and B–5.

(5) Continue laying out the pattern, locating points 2, 1, 6, and 7 by using the same procedures as were used to locate points 3, 4, and 5.

(6) Construct triangles A–E–1 and B–F–7 of the pattern by scribing arcs from points A and B, using a radius equal to the true length of line AE, and scribing arcs from points 1 and 7, using a radius equal to the true length of line E–1. Draw lines through the points of intersection of these arcs.

g. These procedures will develop only one half pattern for the object. The other half pattern can be developed by repeating these procedures or by reversing this pattern when cutting the sheet stock for manufacture of the object. Extra material must be added for the seam to be used. Where object is unsymmetrical (not uniform) the remaining sides also have to be laid out, using a separate true length chart.

17-24. **Making Layouts.** It is wise to make a layout or pattern of the part before forming it to prevent any waste of material and to get a greater degree of accuracy in the finished part. Where straight angle bends are concerned, correct allowances must be made for setback and bend allowance. If the shrinking or stretching processes are to be applied, an accurate estimate of where the metal sheet is to be stretched or shrunk must be made so that the part can be turned out with a minimum amount of forming.

17-25. The layout procedures can be put into three general groups: flat layout, duplication of

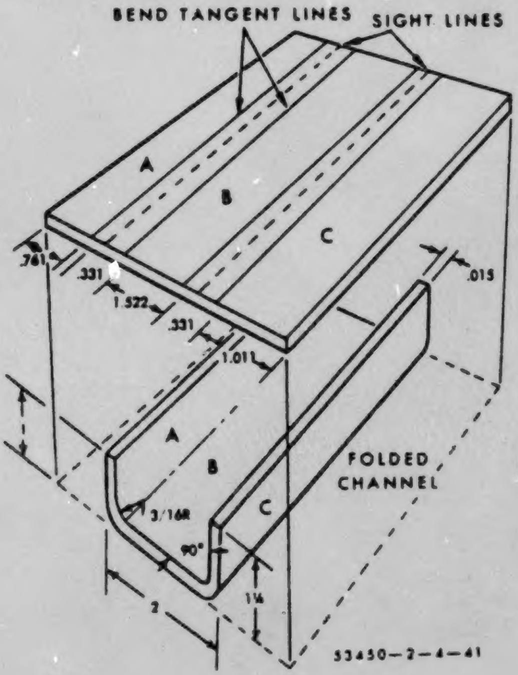


Figure 93. Flat layout of a channel.

pattern, and projection through a set of points. All three processes require a good working knowledge of arithmetic and geometry. Only two processes, flat layout and duplication of pattern, will be discussed here.

17-26. *Flat layout.* Assume that you are to lay out a flat pattern of a channel, as illustrated in figure 93, in which the left-hand flat, A, is to be 1 inch high; the right-hand flat, C, is to be 1¼ inches high; and the distance between the outside surface of the two flats, B, is to be 2 inches. The material is 0.051 inch thick, and the radius of bend is to be 3/16 inch (0.188). The angles are to be 90°. You would proceed as follows:

a. First determine the setback in order to establish the distance of the flats. (The setback for the first bend is R + T, or 0.188 + 0.051 = 0.239. The first flat, A, is equal to the overall dimension less the setback, or 1.000 − 0.239 = 0.761 inch.

b. Next calculate the bend allowance for the first bend by using the bend allowance table (BA = 0.3307 or 0.331).

c. Now lay off these measurements so you know where to begin and end each bend. (Refer to figure 93 for illustration of the steps.)

d. Next lay off the second flat, B. This is equal to the overall dimension less the setback at each end, or B − two setback, or 2.000 − (0.239 + 0.239) 0.478 = 1.522.

e. The bend allowance for the second bend is the same as that for the first bend (0.331). Mark off this distance.

f. The third flat, C, is equal to the overall dimension less the setback, or 1.25 − 0.239 = 1.011. (Lay off this distance as illustrated in figure 93.)

g. Adding the measurements of flats A, B, and C, and both bend allowances (0.761 + 0.331 + 1.522 + 0.331 + 1.011), the sum is 3.956, or approximately 4.00 inches. Totaling the three flats, A, B, and C, 1 inch, 2 inches, and 1¼ inches, respectively, the sum if 4.250 inches of material length. You can see how setback and bend allowance affect material lengths in forming straight line bends. In this case, the reduction is approximately ¼ inch. If the angles were not right angles, you would take the setback values from setback or K-charts.

17-27. After all measurements are calculated, cut the material and mark off the brake or sight lines as shown in figure 93. You are ready to use the brake to form the channel.

17-28. *Duplication of pattern.* When it is necessary to duplicate an aircraft part and blueprints are not available, you may take measurements directly from the original or from a duplicate part. In studying the following steps for laying out a part to be duplicated, refer to the illustrations in figure 94.

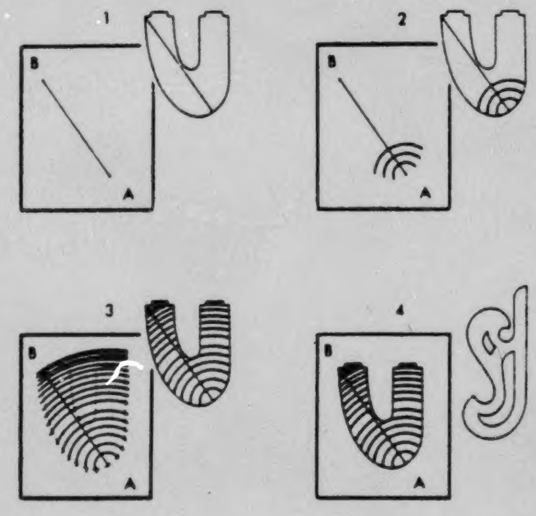
17-29. Draw a reference (datum) line, AB on the sample part, and a corresponding line on the template material (example 1, fig. 94).

17-30. Next, with point A on the sample part as a center, draw an arc having a radius of approximately ½ inch and extending to the flanges. Number the arc as it passes through the reference line (example 2, fig. 94).

17-31. Draw similar arcs each with a radius ½ inch greater than the previous one until you have marked the entire part. In case there is an extremely sharp curve in the object, decrease the distance between the arcs to increase the number of arcs. This procedure will increase the accuracy of the layout. An arc must pass through every corner of the part; one arc may pass through more than one corner (example 3, fig. 94).

17-32. Locate the coordinate point on the layout by measuring on the part with dividers. Always measure the distance from the reference point to the beginning of the bend line on the flange of the part. After you have similarly located all points, draw a line through them, using a French curve to insure a smooth pattern.

17-33. Allow for additional material for forming the flange and locate the inside bend tangent line by measuring, inside the sight line, a distance equal to the radius of bend of the part.



53450—2—4—42

Figure 94. Duplicating a pattern.

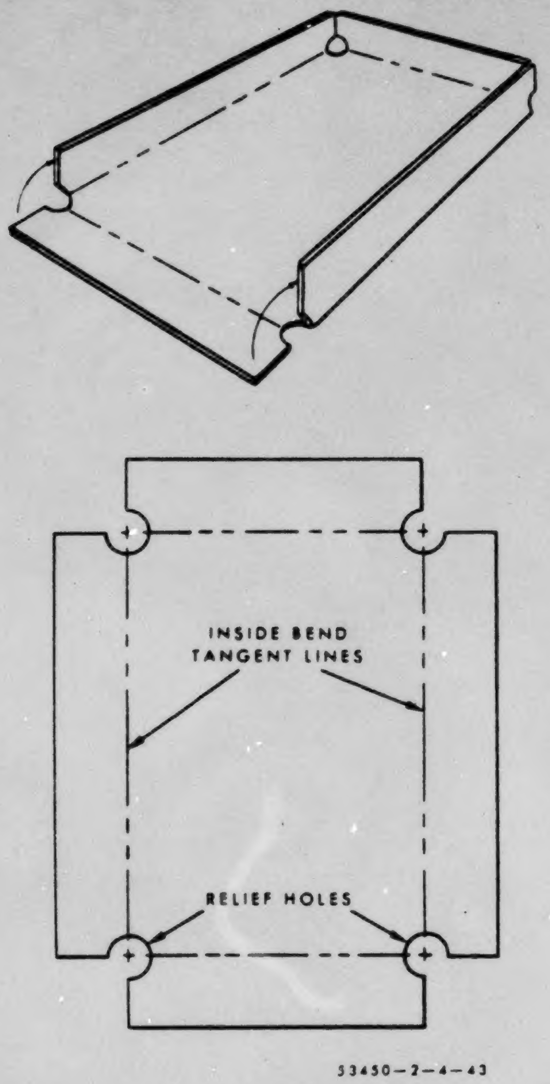


Figure 95. Locating relief holes.

17-34. Using the intersection of the lines as a center, locate the required relief holes. Then cut out and form the part as necessary.

17-35. *Relief holes.* Wherever two bends intersect, material must be removed to make room for the material contained in the flanges. Holes are therefore drilled at the intersection. These holes, called relief holes, prevent strains from being set up at the intersection of the inside bend tangent lines. Such strains may cause the metal to crack. Relief holes also provide a neatly trimmed corner where the excess material is trimmed away.

17-36. The size of the relief holes varies with thickness of the material. They should not be less than ⅛ inch in diameter for aluminum alloy sheet stock up to and including 0.064 inch thick, or 3/16 inch for stock ranging in thickness from 0.072 inch to 0.128 inch. The most common method of determining the diameter of a relief hole is to use the radius of bend for this dimension, provided it is not less than the minimum allowance (⅛ inch).

17-37. Relief holes must touch the intersection of the inside bend tangent lines. To allow for possible error in bending, make relief holes extend 1/32 to 1/16 inch behind the inside bend tangent lines. It is good practice to use the intersection of these lines as center for relief holes (see fig. 95). The line on the inside of the curve is cut at an angle toward the relief holes to allow for the stretching of the inside flange.

17-38. *Lightening holes.* Occasionally, holes are cut in rib sections, fuselage frames, and other structural parts to decrease weight. Such holes are known as lightening holes. To keep from weakening the member (by removal of the material), flanges are often pressed around the holes to strengthen the area from which the material was removed.

17-39. These holes should never be cut in any structural part unless authorized. The size of the lightening hole and the width of the flange formed around the hole are determined by design specifications. Margins of safety are considered in the specifications so that the weight of the part can be decreased and still retain the necessary strength. You may cut out lightening holes by any one of the following methods:

a. Punching out, if the correct size punch die is available.

b. Cutting with a fly-cutter mounted on a drill.

c. Scribing the circumference of a hole with dividers and drilling around the entire circumference with a small drill, allowing enough clearance for proper smoothness after filing.

d. Scribing the circumference of the hole with dividers, drilling the hole inside the circumference large enough to insert aviation snips, cutting out excess metal, and filing to a smooth finish.

17-40. Form the flange by using a flanging die, hardwood, or metal form blocks. Flanging dies consist of two matching parts—a female and a male die. For flanging soft metal, dies can be of hardwood, such as maple. For hard metal or for more permanent use, dies should be made of steel. The pilot guide should be of the same size as the hole to be flanged, and the shoulder should be the same width and angle as the desired flange.

17-41. When flanging lightening holes, place the material between the mating parts of the die and form it by hammering or squeezing the dies together in a vise or in an arbor press. The dies

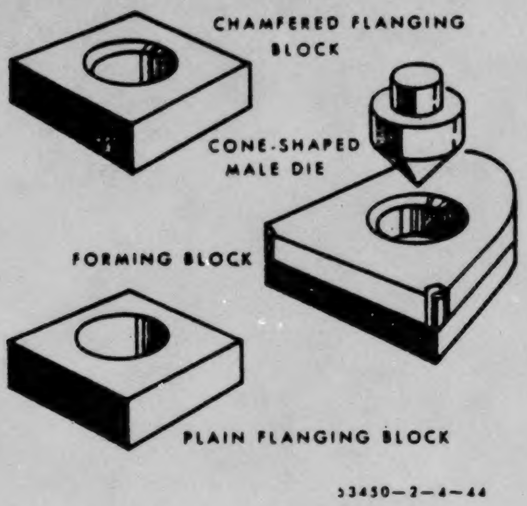


Figure 96. Flanging form blocks.

will work more smoothly if they are coated with light machine oil.

17-42. Note that in the two form blocks shown on the left side of figure 96, the hole in the upper block is the same size as the hole to be flanged. The hole is chamfered to the width of the flange and the angle desired, while the lower block, the hole is the same diameter as that of the flange. You may use either type. When using the upper block, center the material to be flanged and hammer it with a stretching mallet, around and around, until the flange conforms to the chamfer. When using the lower block, center the lightening hole over the hole in the block, then stretch the edges, hammering the material into the hole, around and around, until the desired flange is obtained.

17-43. Occasionally, the chamfer is formed with a cone-shaped male die used in conjunction with the form block with which the part was formed as illustrated in figure 96.

17-44. **Making Straight Line Bends.** When forming straight bends, you must consider the thickness of the material, its alloy composition, and its temper condition. Generally speaking, the thinner the material, the sharper it can be bent (the smaller the radius of bend); and the softer the material, the sharper the bend.

17-45. The sharpest bend that can be placed in a piece of metal without critically weakening the part is called the minimum radius of bend. Other factors that must be considered when making straight line bends are bend allowance, setback, and brake or sight line.

17-46. Formulas and tables to be applied under the varying conditions have been established for your use. Application of the formulas usually consists merely of subsituting measurements, such as sheet stock thickness and degree of bends. All these tables and formulas are based on the decimal system. If sheet stock thicknesses are given in gage numbers, you must convert them to their decimal equivalent before you can proceed with your calculations.

17-47. *Radius of bend.* The radius of bend of a sheet of material is the radius of bend as measured on the inside of the curved material. The minimum radius of a sheet of material is the sharpest curve, or bend, to which the sheet can be bent without critically weakening the portion at the bend. If the radius of bend is too small, stresses and strains will weaken the metal and may result in cracking.

17-48. A minimum radius of bend is specified for each type of aircraft sheet metal. The kind of material, thickness, and temper condition of the sheet are factors affecting it. You may bend annealed sheet to a radius approximately equal to its thickness. Stainless steel and 2024–T aluminum alloy require a fairly large bend radius.

17-49. *Bend allowance.* Suppose you were confronted with the problem of making a formed angle or a stringer to fit into a corner. The corner measures 1 inch on each side, but you realize that you cannot make a square bend in the metal and that it will not fit squarely into the corner because it will have a curve. You know, also, that the curved distance will be shorter than the distance into the corner and out. When making a bend or fold in a sheet of metal, you must calculate bend allowance—the length of material required for the bend.

17-50. Bend allowance depends on four factors: the degree of bend, the radius of the bend, the thickness of the material, and the type of metal used. The radius of the bend is generally proportional to the thickness of the material. Furthermore, the sharper the radius of bend can be made, the shorter will be the material needed for the bend. The type of material is also important, for if the material is soft it can be bent very sharply, but if hard, the radius of bend will be greater and bend allowance will be greater. The degree of bend will affect the overall length of the metal, whereas the thickness influences the radius of bend.

17-51. Bending the strip would compress the material on the inside of the curve and stretch the material outside it. However, at some distance between these two extremes lies a space that is not affected by either force. This is known as the neutral line or neutral axis. It occurs at a distance approximately 0.445 of the metal thickness (0.455 × T) from the inside of the radius of bend. (See fig. 97.)

17-52. When bending metal to exact dimensions, the length of the neutral line must be determined in order that sufficient material can be allowed for the bend. To save you time in calculation of the bend allowance, formulas and charts for various angles, radii of bends, material thicknesses, and other factors have been established for your use. The bend allowance formula for a 90° bend can be derived as follows.

17-53. To the radius of bend, *R*, add one-half the thickness of the metal, ½ *T*. This gives *R* + ½ *T*, or the radius of the circle of approximately the neutral axis.

17-54. Compute the circumference of this circle by multiplying the radius of curvature of the neutral line ($R + \frac{1}{2} T$ in the illustration) by 2π. This gives the circumference as

$$2\pi(R + \tfrac{1}{2} T)$$

17-55. Since a 90° bend (AB in fig. 97) is a quarter of the circle, divide the circumference by 4. This gives

$$\frac{2\pi(R + \frac{1}{2} T)}{4}$$

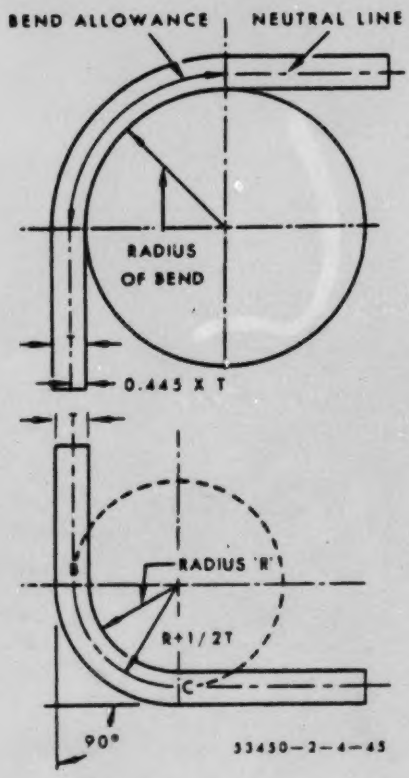


Figure 97. Bend allowance 90° bend.

17-56. To use the formula in finding the bend allowance for a 90° bend having a radius of ¼ inch for material 0.051 inch thick, substitute in the formula as follows:

Bend allowance

$$= \frac{2 \times 3.1416\,(.250 + \frac{1}{2}\,(.051)\,)}{4}$$

$$= \frac{6.2832\,(.250 + .0255)}{4}$$

$$= \frac{6.2832\,(.2755)}{4}$$

= ~~.4323~~ .4327

17-57. The necessary bend allowance or the length of material required for the bend is 0.4323 or 7/16 inch.

17-58. The formula is slightly in error because, actually, the neutral line is not exactly in the center of the sheet being bent (see fig. 97). However, the amount of error incurred in any given problem is so slight that, for most work, since the material used is thin, the formula is satisfactory.

17-59. This formula may be used in the absence of a bend allowance chart. To determine bend allowance for any degree of bend by use of the chart (table 39), find the allowance per degree for the thickness of the material and the radius of bend in question, and then multiply by the number of degrees in the bend.

17-60. Radius of bend is given as a decimal fraction on the top line of the chart. Bend allowance is given directly below the radius figures. The top number in each case is the bend allowance for a 90° angle, while the lower placed number is for a 1° angle. Material thickness is given in the left column of the chart.

17-61. To find the bend allowance when the sheet thickness is 0.051 inch, the radius of bend is ¼ inch (0.250-inch), and the bend is to be 90°, look at the bend allowance chart (table 39). Reading across the top of the chart, find the column for a radius of bend of 0.250 inch. Now find the block in this column that is opposite the gage of .051 in the column at left. The upper number in the block is .428, the correct bend allowance in inches for a 90° bend.

17-62. If the bend is to be other than 90°, you must use the lower number in the block (the bend allowance for 1°) and compute the bend allowance. The lower number in this case is .004756. Therefore, if the bend is to be 120°, your total bend allowance in inches will be 120 × .004756, or .5707 inch.

17-63. *Setback.* When bending a piece of sheet stock, it is necessary to know the starting and ending points of the bend so that the length of the "flat" of the stock can be determined. Two

206

TABLE 39

BEND ALLOWANCE CHART

RADIUS GAGE	.031	.063	.094	.125	.156	.188	.219	.250	.281	.313	.344	.375	.438	.500
.020	.062 .000693	.113 .001251	.161 .001792	.210 .002333	.259 .002874	.309 .003433	.358 .003974	.406 .004515	.455 .005056	.505 .005614	.554 006155	.603 006695	702 007795	.799 .008877
.025	.066 .000736	.116 .001294	.165 .001835	.214 .002376	.263 .002917	.313 .003476	.362 .004017	.410 .004558	.459 .005098	.509 .005657	.558 .006198	.607 .006739	705 007838	803 .008920
.028	.068 .000759	.119 .001318	.167 .001859	.216 .002400	.265 .002941	.315 .003499	.364 .004040	.412 .004581	.461 .005122	.511 .005680	.560 .006221	.609 .006762	.708 .007862	805 007862
.032	.071 .000787	.121 .001345	.170 .001886	.218 .002427	.267 .002968	.317 .003526	.366 .004067	.415 .004608	.463 .005149	.514 .005708	.562 .006249	.611 .006789	.710 .007889	.807 .008971
.038	.075 .000837	.126 .001396	.174 .001937	.223 .002478	.272 .003019	.322 .003577	.371 .004118	.419 .004659	.468 .005200	.518 .005758	.567 .006299	.616 .006840	.715 .007940	.812 .009021
.040	.077 .000853	.127 .001411	.176 .001952	.224 .002493	.273 .003034	.323 .003593	.372 .004134	.421 .004675	.469 .005215	.520 .005774	.568 .006315	.617 .006856	.716 .007955	.813 .009037
.051		.134 .001413	.183 .002034	.232 .002575	.280 .003116	.331 .003675	.379 .004215	.428 .004756	.477 .005297	.527 .005855	.576 .006397	.624 .006934	.723 .008037	821 .009119
.064		.144 .001595	.192 .002136	.241 .002676	.290 .003218	.340 .003776	.389 .004317	.437 .004858	.486 .005399	.536 .005957	.585 .006498	.634 .007039	.732 .008138	.830 .009220
.072			.198 .002202	.247 .002743	.296 .003284	.436 .003842	.394 .004283	.443 .004924	.492 .005465	.542 .006023	.591 .006564	.639 .007105	.738 .008205	.836 .009287
.078			.202 .002249	.251 .002790	.300 .003331	.350 .003889	.399 .004430	.447 .004963	.496 .005512	.546 .006070	.595 .006611	.644 .007152	.745 .008252	.840 .009333
.081			.204 .002272	.253 .002813	.302 .003354	.352 .003912	.401 .004453	.449 .004969	.498 .005535	.548 .006094	.598 .006635	.646 .007176	.745 .008275	.842 .009357
.091			.212 .002350	.260 .002891	.309 .003432	.359 .003990	.408 .004531	.456 .005072	.505 .005613	.555 .006172	.604 .006713	.653 .007254	.752 .008353	.849 .009435
.094			.214 .002374	.262 .002914	.311 .003455	.361 .004014	.410 .004555	.459 .005096	.507 .005637	.558 .006195	.606 .006736	.655 .007277	.754 .008376	.851 .009458
.102				.268 .002977	.317 .003518	.367 .004076	.416 .004617	.464 .005158	.513 .005699	.563 .006257	.612 .006798	.661 .007339	.760 .008439	.857 .009521
.109				.273 .003031	.321 .003572	.372 .004131	.420 .004672	.469 .005213	.518 .005754	.568 .006312	.617 .006853	.665 .008394	.764 .008493	.862 009575
.125				.284 .003156	.333 .003697	.383 .004256	.432 .004797	.480 .005338	.529 .005678	.579 .006437	.628 006978	.677 .007519	.776 .008618	.873 .009700
.156					.355 .003939	.405 .004497	.453 .005038	.502 .005579	.551 .006120	.601 .006679	.650 .007220	.698 .007761	.797 008860	.895 .009942
.188						.417 .004747	.476 .005288	.525 .005829	.573 .006370	.624 .006928	.672 .007469	.721 008010	.820 .009109	.917 .010191
.250								.568 .006313	.617 .006853	.667 .007412	.716 .007953	.764 .008494	.863 .009593	.961 .010675

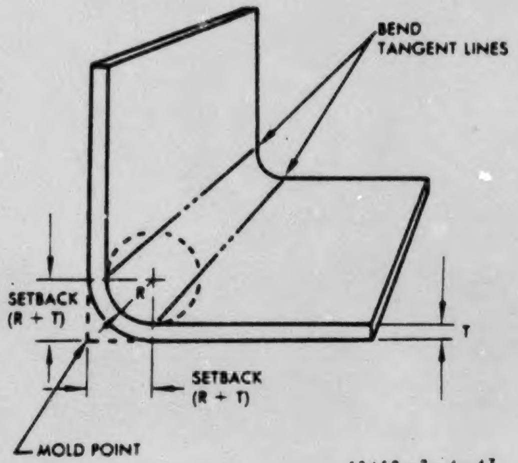
53450-2-4-46

factors are important in determining this—the radius of bend and the thickness of the material.

17-64. In figure 98, note that setback is the distance from the bend tangent line to the mold point. The mold point is the point of intersection of the lines extending from the outside surfaces, while the bend tangent lines are the starting and end points of the bend. Also note that setback is the same for the vertical flat and the horizontal flat.

17-65. To calculate the setback for a 90° bend, merely add the inside radius of the bend to the thickness of the sheet stock. In formula, this would read $SB = R + T$.

17-66. To calculate setback for angles larger or smaller than 90°, you have to consult setback charts (as illustrated in table 40), or K-charts, for a value called K and then substitute this value in the formula $SB = K\ (R + T)$. The value for K varies with the number of degrees in the bend.



53450-2-4-47

Figure 98. Setback 90° bend.

218

TABLE 40

SETBACK (K) CHART

A	K	A	K	A	K
1°	.00873	61°	58904	121°	1.7675
2°	.01745	62°	.60086	122°	1.8040
3°	.02618	63°	.61280	123°	1.8418
4°	.03492	64°	.62487	124°	1.8807
5°	.04366	65°	.63707	125°	1.9210
6°	.05241	66°	.64941	126°	1.9626
7°	.06116	67°	.66188	127°	2.0057
8°	.06993	68°	.67451	128°	2.0503
9°	.07870	69°	.68728	129°	2.0965
10°	.08749	70°	.70021	130°	2.1445
11°	.09629	71°	.71329	131°	2.1943
12°	.10510	72°	.72654	132°	2.2460
13°	.11393	73°	.73996	133°	2.2998
14°	.12278	74°	.75355	134°	2.3558
15°	.13165	75°	.76733	135°	2.4142
16°	.14054	76°	.78128	136°	2.4751
17°	.14945	77°	.79543	137°	2.5386
18°	.15838	78°	.80978	138°	2.6051
19°	.16734	79°	.82434	139°	2.6746
20°	.17633	80°	.83910	140°	2.7475
21°	18534	81°	.85408	141°	2.8239
22°	.19438	82°	.86929	142°	2.9042
23°	.20345	83°	.88472	143°	2.9887
24°	.21256	84°	.90040	144°	3.0777
25°	.22169	85°	.91633	145°	3.1716
26°	.23087	86°	.93251	146°	3.2708
27°	.24008	87°	.80978	147°	3.3759
28°	.24933	88°	.96569	148°	3.4874
29°	25862	89°	.98270	149°	3.6059
30°	26795	90°	1.0000C	150°	3.7320
31°	.27732	91°	1.0176	151°	3.8667
32°	.28674	92°	1.0355	152°	4.0108
33°	.29621	93°	1.0538	153°	4.1653
34°	.30573	94°	1.0724	154°	4.3315
35°	.31530	95°	1.0913	155°	4.5107
36°	.32492	96°	1.1106	156°	4.7046
37°	.33459	97°	1.1303	157°	4.9151
38°	.34433	98°	1.1504	158°	5.1455
39°	.35412	99°	1.1708	159°	5.3995
40°	.36397	100°	1.1917	160°	5.6713
41°	.37388	101°	1.2131	161°	5.9758
42°	38386	102°	1.2349	162°	6.3137
43°	.39391	103°	1.2572	163°	6.6911
44°	.40403	104°	1.2799	164°	7.1154
45°	.41421	105°	1.3032	165°	7.5957
46°	.42447	106°	1.3270	166°	8.1443
47°	.43481	107°	1.3514	167°	8.7769
48°	.44523	108°	1.3764	168°	9.5144
49°	.45573	109°	1.4019	169°	10.385
50°	.46631	110°	1.4281	170°	11.430
51°	47697	111°	1.4550	171°	12.706
52°	.48773	112°	1.4826	172°	14.301
53°	.49858	113°	1.5108	173°	16.350
54°	.50952	114°	1.5399	174°	19.081
55°	.52057	115°	1.5697	175°	22.904
56°	53171	116°	1.6003	176°	26.636
57°	54295	117°	1.6318	177°	38.188
58°	55431	118°	1.6643	178°	57.290
59°	.56577	119°	1.6977	179°	114.590
60°	57735	120°	1.7320	180°	Infinite

53450—2—4—48

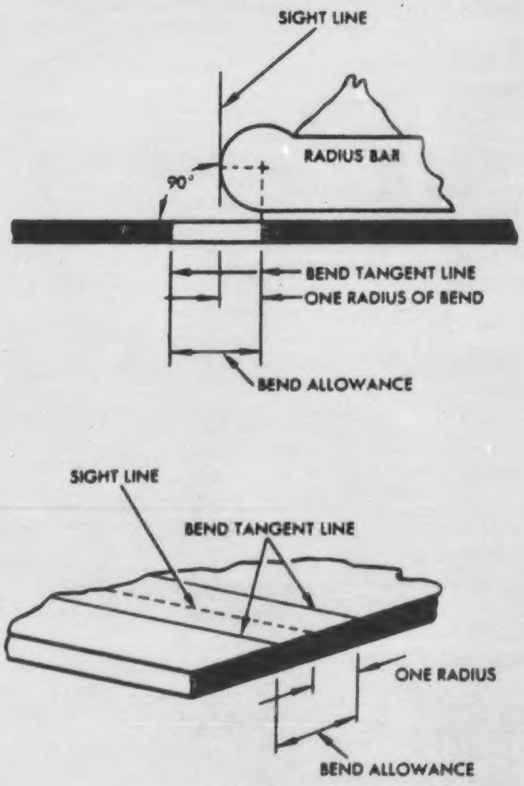
17-67. For a 90° bend, if the material is 0.051 inch thick and the radius of bend is specified to be ⅛ inch (0.125), substitute in the formula $SB = R + T$ and solve as follows:

$$SB = 0.125 + 0.051 = 0.176\text{-inch setback}$$

17-68. For a 120° bend with a radius of bend of 0.125 inch in a sheet 0.032 inch thick, obtain the value of K from the setback chart (K for 120° bend = 1.732), substitute in the formula $SB = K(R + T)$ and solve as follows:

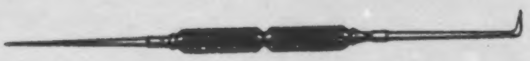
$$SB = 1.732\ (.032 + .125) = .272\text{ inch}$$

17-69. *Brake or sight line.* The brake or sight line is the mark on a flat sheet of stock which is set so as to be even with the nose of the radius bar of the cornice brake. It serves as a guide in bending. You can locate the brake line by measuring out one radius from the bend tangent line which is to be inserted under the nose of the brake or against the radius form block as illustrated in figure 99.



53450—2—4—49

Figure 99. Brake or sight line.



53450-2-4-50

Figure 100. Scriber.

17-70. *Scriber.* The scriber is designed to serve the airframe repairman in the same way a pencil or pen serves a writer. In general, it is used to scribe or mark lines on metal surfaces. The scriber illustrated in figure 100, is made of tool steel, 4 to 12 inches long, and has two needle-pointed ends. One end is bent at a 90° angle for reaching and marking through holes.

17-71. Before using a scriber, always inspect the points for sharpness. Be sure the steel rule being used as a straightedge is flat on the metal and in position for scribing. Tilt the scriber slightly in the direction toward which it will be moved, holding it like a pencil. Keep the scriber's point close to the guiding edge of the steel rule. The scribed line should be heavy enough to be visible, but no deeper than necessary to serve its purpose.

17-72. Before we continue to Section 18, turn to the workbook and answer questions for this section.

18. Folding and Forming Equipment

18-1. Once you have determined the working dimensions of a piece or part to be attached to an aircraft, you have two basic ways of developing the item from paper to metal. Either you bend and form the metal by hand or by machine. In this section, we will discuss some of the machines necessary for forming and folding metal into usable parts, their operation, and maintenance. We will include the bar folder, cornice brake, box and pan brake, slip roll former, rotary machines, flanging machines, shrinking and stretching machines, and the arbor press.

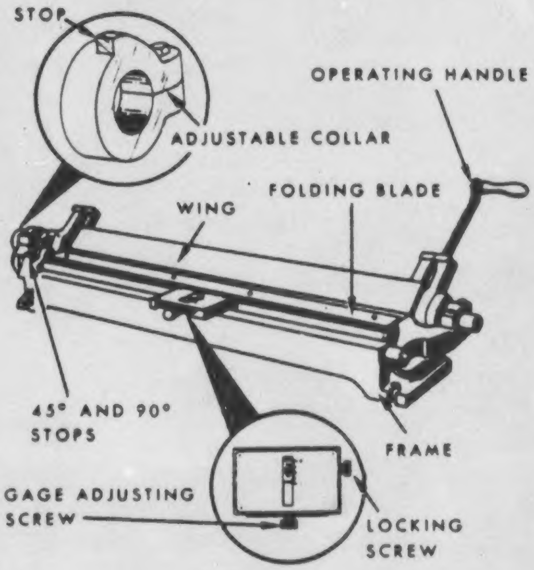
18-2. The machines mentioned are not the only machines available to you for forming metal, but are the ones generally found in most airframe repair shops. Many of these machines are similar in nature and you should decide which to use by the size and shape of the part to be formed. With only slight variation, many jobs can be done on the same machine, to avoid changing from one to another when forming or folding metal.

18-3. **Bar Folder.** The bar folder shown in figure 101 is designed for use in making bends or folds along edges of sheets of metal. This machine is best suited for folding small hems, flanges, seams, and edges to be wired. Most bar folders have a capacity for metal up to 22 gage in thickness and 42 inches in length. Before using the bar folder you must make several adjustments, including adjustments for thickness of material, width of fold, sharpness of fold, and angle of fold.

18-4. *Thickness of material.* The adjustment for thickness of material is made by adjusting the screws at each end of the folder. As this adjustment is made, place a piece of metal of the desired thickness in the folder and raise the operating handle until the small roller rests on the cam. Hold the folding blade in this position and adjust the setscrews so the metal is clamped securely and evenly the full length of the folding blade. After the folder has been adjusted, test each end of the machine separately with a small piece of metal by actually folding it.

18-5. Be extremely careful not to overadjust the bar folder so that the clamping pressure is too great, because such an adjustment will damage the clamping blade. This condition is easy to avoid because the machine should operate freely. If it does not operate freely, the clamping blade is too tight.

18-6. *Width of fold.* The width of fold is controlled by the adjusting screws shown in the inset view of figure 101. The gage adjusting screw moves the slide and gage back and forth for the width of the desired fold. The gage is graduated in fractions of an inch from 0 to 1 inch, since a 1-inch fold is the largest that can be made on this folder. After the adjustment is made, lock the gage in place by tightening the lockscrew which



53450-2-4-64

Figure 101. Bar folder.

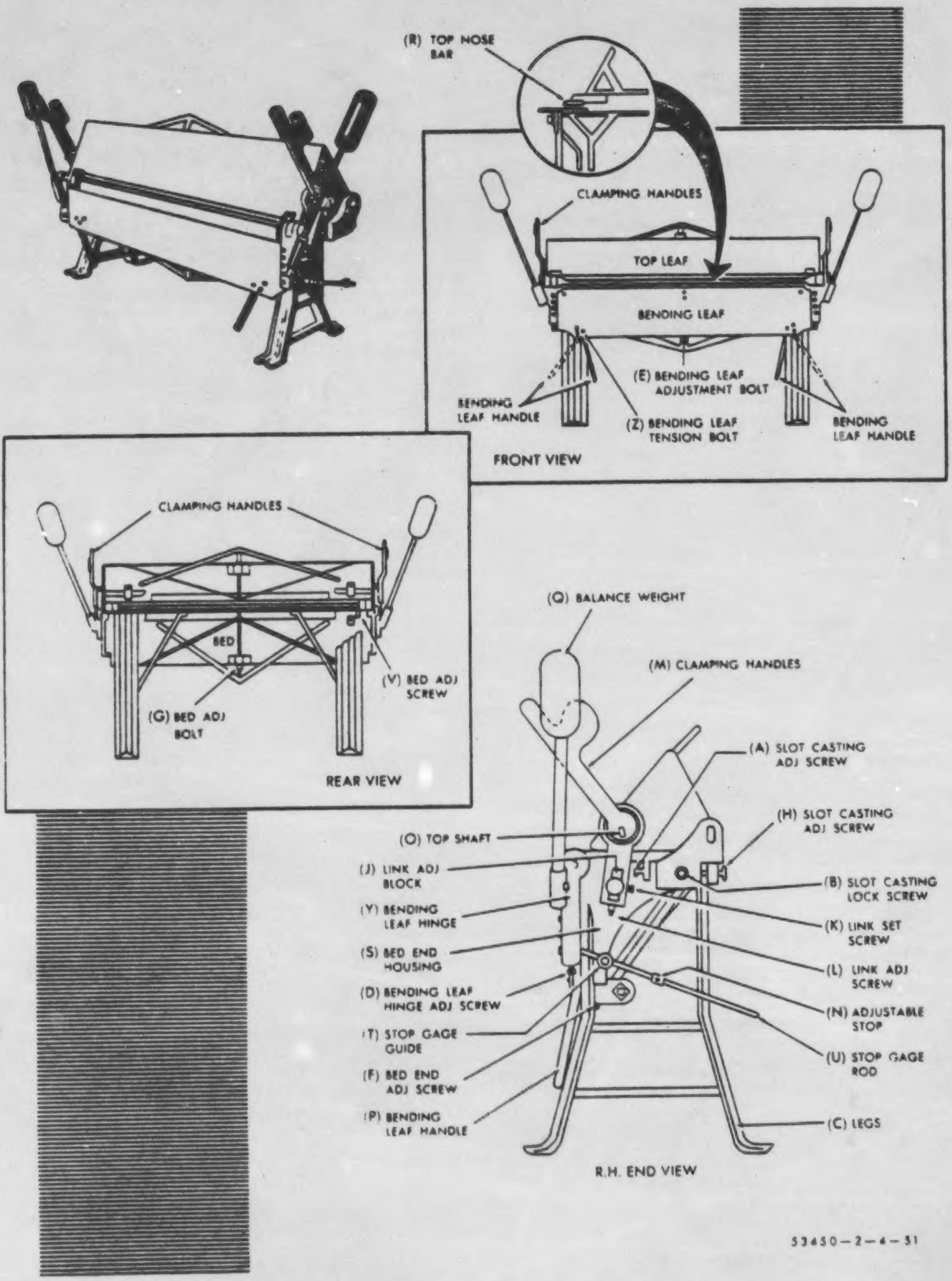

(R) TOP NOSE BAR
CLAMPING HANDLES
TOP LEAF
BENDING LEAF
(E) BENDING LEAF ADJUSTMENT BOLT
BENDING LEAF HANDLE
(Z) BENDING LEAF TENSION BOLT
BENDING LEAF HANDLE
FRONT VIEW
CLAMPING HANDLES
BED
(V) BED ADJ SCREW
(G) BED ADJ BOLT
REAR VIEW
(Q) BALANCE WEIGHT
(M) CLAMPING HANDLES
(A) SLOT CASTING ADJ SCREW
(H) SLOT CASTING ADJ SCREW
(O) TOP SHAFT
(J) LINK ADJ BLOCK
(B) SLOT CASTING LOCK SCREW
(Y) BENDING LEAF HINGE
(K) LINK SET SCREW
(S) BED END HOUSING
(L) LINK ADJ SCREW
(D) BENDING LEAF HINGE ADJ SCREW
(N) ADJUSTABLE STOP
(T) STOP GAGE GUIDE
(U) STOP GAGE ROD
(F) BED END ADJ SCREW
(P) BENDING LEAF HANDLE
(C) LEGS
R.H. END VIEW
53450—2—4—31

Figure 102. Cornice brake.

is located on the right side of the gage. If it is necessary to fold greater than 1 inch, the cornice brake must be used.

18-7. *Sharpness of fold.* The bar folder can be used for making either sharp or round folds. The sharpness of the fold is controlled by raising or lowering the wing. This requires the proper adjustment of the wedge which supports the wing. The wedge adjusting knob is located in the center of the folding blade. Before the wedge adjustment can be made, the wing must be perpendicular to the folding blade. To make a sharp fold, set the wedge so the wing will stay in the same position through a cycle of operation. To make a round fold, adjust the wedge so that the wing will be forced back when you make your fold.

18-8. *Angle of fold.* There are two positive stops on the folder, one for 45° folds or bends and the other for 90° folds or bends. An additional feature (a collar) is provided and can be adjusted to any degree of bend within the capacity of the machine. For forming angles of 45° or 90°, the correct stop is moved into place. This will allow you to move the handle forward to the correct angle. For forming other angles, use the adjustable collar shown in the inset of figure 101. This is done by loosening the setscrew and setting the stop at the desired angle. After setting the stop, tighten the setscrew and complete the bend.

18-9. *Making the fold.* To make the fold, adjust the machine correctly, using the procedures given above, and then insert the metal. The metal goes between the folding blade and jaw. Hold the metal firmly against the gage as you pull the operating handle toward you. As the handle is brought forward, the jaw automatically raises and holds the metal until the desired fold is made. When the handle is returned to its original position, the jaw and blade will return to their original positions and release the metal.

18-10. **Cornice Brake.** The cornice brake has a much greater range of usefulness than the bar folder. Any bend formed on a bar folder can be formed on the cornice brake. The bar folder can form a bend or edge only as wide as the depth of the jaws. In comparison, the cornice brake allows the sheet to pass through the jaws from front to rear without obstruction.

18-11. When you make ordinary bends with the cornice brake, place the sheet on the bed with the sight line (mark indicating line of bend) directly under the edge of the clamping bar. Then bring the clamping bar down to hold the sheet firmly in place. Set the stop at the right side of the brake for the proper angle or amount of bend and raise the bending leaf until it strikes the stop. If other bends are to be made, lift the clamping bar and move the sheet to the correct position for bending.

18-12. When bending sheets heavier than 22 gage, raise the clamping bar an amount equal to the thickness of the metal and set it back the same distance. When bending sheets heavier than 22 gage, reinforce the bending leaf with angle iron.

18-13. *Adjustment of brake.* To get the most out of a brake, you have to know how to adjust it for various operations. These adjustments are very important, as they save time and improve the quality of your work. They are listed below:

a. The cornice brake must be level on the floor. If the cornice brake is not level, the top leaf will creep when clamping metal between jaws. If the top leaf does creep, adjust setcrew H and capscrew B shown in figure 102. If this does not remedy the creeping, place a wedge of wood or similar material under the rear leg at point C on the side that creeps. After the creeping is eliminated, replace the wedge with a permanent block of the proper thickness.

b. Check the bending leaf when it is in the down position. The edge of this leaf should be $^{1}/_{64}$ inch below the bed edge of the ends and $^{1}/_{32}$ inch below the bed edge at the center. To obtain and maintain this alignment:

- Adjust leaf ends with screws D.
- Adjust leaf center with bolt E.
- Adjust bed ends with screws F.
- Adjust bed ends with bolt G.

c. In bending various thicknesses of sheet metal stock with the cornice brake, it is recommended that you move the upper nose bar back at the bending edge. If the material to be bent is within 4 gages of the capacity of the machine, move the top leaf back twice the thickness of the material. When sharp bends are to be made on lightweight metal, move the top leaf foward. To adjust the top leaf:

- Loosen screws B (fig. 102).
- Move the top leaf forward or backward by adjusting screws A or H. (These screws have right-hand threads.)
- Once the correct adjustment is made, lock adjustment with screws B.

d. The clamping pressure should be tight enough to hold the metal in place while the bend is being made. Different gages of metal require different adjustments, so you must realize that every gage of metal will have its own adjustment. Remember, the pressure should be equal

Decimal Equivalents

FRACTION	16TH	32ND	64TH	DECIMAL	FRACTION	16TH	32ND	64TH	DECIMAL
			1	015625				33	515625
		1	2	03125			17	34	53125
			3	046875				35	546875
	1	2	4	0625		9	18	36	5625
			5	078125				37	578125
		3	6	09375			19	38	59375
			7	109375				39	609375
⅛	2	4	8	125	⅝	10	20	40	625
			9	140625				41	640625
		5	10	15625			21	42	65625
			11	171875				43	671875
	3	6	12	1875		11	22	44	6875
			13	203125				45	703125
		7	14	21875			23	46	71875
			15	234375				47	734375
¼	4	8	16	250	¾	12	24	48	750
			17	265625				49	765625
		9	18	28125			25	50	78125
			19	296875				51	796875
	5	10	20	3125		13	26	52	8125
			21	328125				53	828125
		11	22	34375			27	54	84375
			23	359375				55	859375
⅜	6	12	24	375	⅞	14	28	56	875
			25	390625				57	890625
		13	26	40625			29	58	90625
			27	421875				59	921875
	7	14	28	4375		15	30	60	9375
			29	453125				61	953125
		15	30	46875			31	62	96875
			31	484375				63	984375
½	8	16	32	500	1	16	32	64	1 000

530-2547A

Figure 125. Decimal equivalent chart.

Example: Use figure 125 and determine the decimal equivalent of 1/64, 5/32, 5/16, and ⅞.

1/64 = 0.015625
5/32 = 0.15625
5/16 = 0.3125
7/8 = 0.875

22-9. **Adding Decimals.** To add numbers containing decimals, you must align the decimal points in a vertical column.

Example: Find the sum of 13.01, 0.037, and 1.3.

$$\begin{array}{r} 13.01 \\ 0.037 \\ \underline{1.3} \\ 14.347 \end{array}$$

22-10. **Subtracting Decimals.** To subtract decimal fractions, align the decimal points as in addition and determine the difference.

Example: Subtract 2.84 from 15.1.

$$\begin{array}{r} 15.10 \\ \underline{2.84} \\ 12.26 \end{array}$$

22-11. **Multiplying Decimals.** To multiply decimal numbers, place the multiplier under the multiplicand, disregarding the position of the decimal points. Multiply as with whole numbers, and in the product point off as many decimal places as there are decimal places in both multiplier and multiplicand, beginning at the right, and adding ciphers (zeros) as necessary.

Examples:

a.

$$\begin{array}{r} .25 \\ \underline{2.5} \\ 125 \\ \underline{50} \\ .625 \end{array}$$

b.

$$\begin{array}{r} 11.25 \\ \underline{.75} \\ 5625 \\ \underline{7875} \\ 8.4375 \end{array}$$

c.

$$\begin{array}{r} .05 \\ \underline{.5} \\ .025 \end{array}$$

curves in flat sheet stock. The machine is simply constructed and consists of right- and left-end frames (housings) between which are mounted three solid steel rolls—two lower rolls and one upper roll. The two lower rolls are connected by gears operated by a handcrank. The lower front roll can be adjusted to the thickness of the metal by means of two knurled adjusting screws (one at each end of the roll). Once the metal is started into the machine, it is gripped between the lower front roll and the upper roll and is carried to the lower rear roll which bends it around the upper roll, thus forming a cylinder. If the adjusting screws at each end of the lower rear roll are turned to the right, a smaller radius will be produced; if the screws are turned to the left, a larger radius will be produced.

18-23. On most hand-operated slip roll forming machines the upper roll can be released at one end which permits a formed cylinder to be removed from the machine without distortion. The rolls are grooved on the right end for forming wire and wired edges. The capacity of slip roll forming machines is determined by the manufacturer and must not be exceeded.

18-24. Slip roll operation is not a set procedure; however, the following is recommended: The lower front roll must be adjusted so that it and the upper roll will have a uniform grip on the metal. Once this adjustment has been made, the metal should ride smoothly through the rolls. In making a preliminary test it is best to select a piece of scrap material of the same gage as the metal you plan to form. Crank the test piece through the gripping rolls until it comes in contact with the lower rear roll. Then by means of

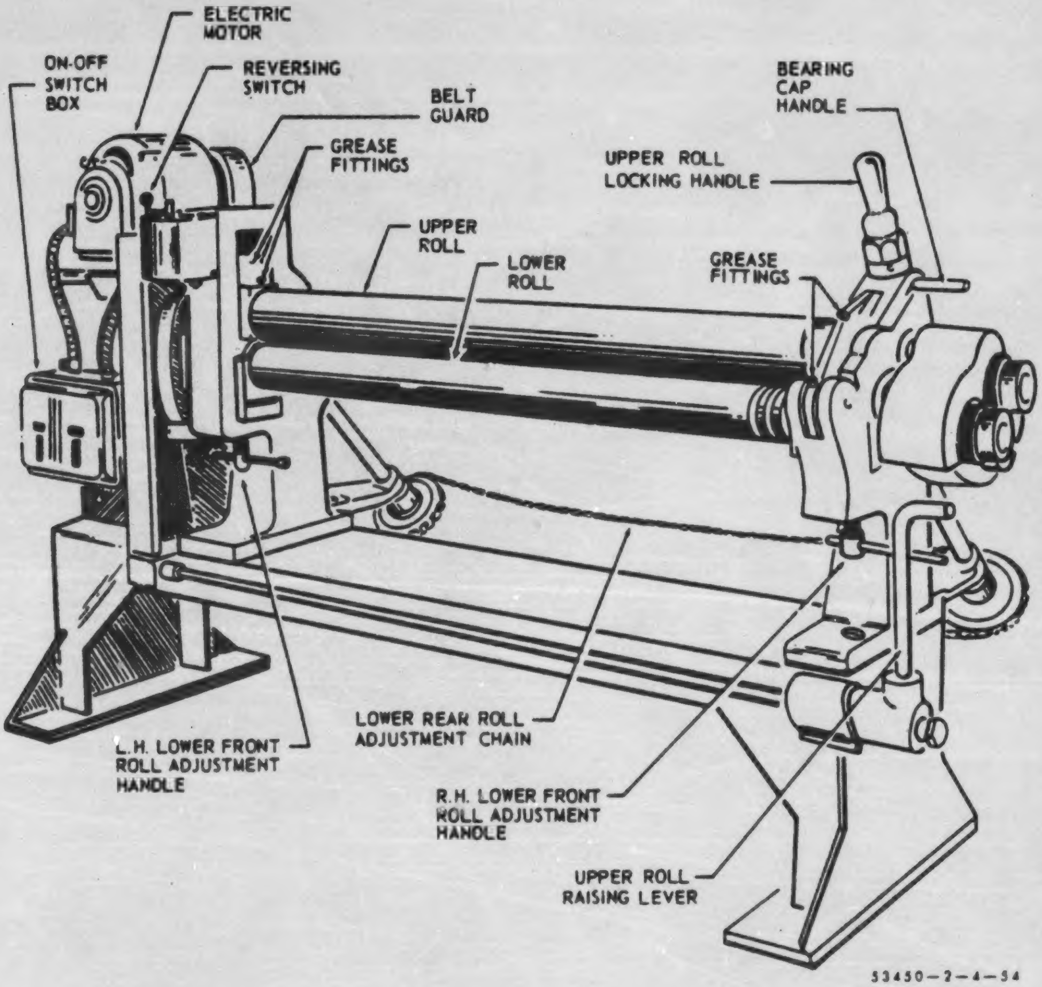

ELECTRIC MOTOR
ON-OFF SWITCH BOX
REVERSING SWITCH
BELT GUARD
GREASE FITTINGS
BEARING CAP HANDLE
UPPER ROLL LOCKING HANDLE
UPPER ROLL
LOWER ROLL
GREASE FITTINGS
LOWER REAR ROLL ADJUSTMENT CHAIN
L.H. LOWER FRONT ROLL ADJUSTMENT HANDLE
R.H. LOWER FRONT ROLL ADJUSTMENT HANDLE
UPPER ROLL RAISING LEVER
53450—2—4—54

Figure 105. Power-operated slip roll forming machine.

on both ends of the machine. This clamping pressure can be changed by adjusting the link blocks J as follows:

- Loosen screws R.
- Loosen screws K which hold link adjustment blocks J.
- Adjust blocks to thickness of metal with screws L.
- Lock adjustment with screws K.
- Use a test strip to be sure that the machine is correctly adjusted.

e. Repeat the above procedures if necessary.

18-14. The bending capacity of a cornice brake is determined by the manufacturer. Standard capacities of this machine are from 22- to 12-gage sheet metal, and bending lengths are from 3 to 12 feet. The bending capacity of the brake is determined by the bending edge thickness of the various bending leaf bars.

18-15. Most metals have a characteristic known as springback. They have a tendency to return to their normal shape. If you set your cornice brake for a 90° bend, the metal bent will probably form an angle of about 87° to 88°. Therefore, if a bend of 90° is desired, you should set your cornice brake to bend an angle of about 93° to allow for springback.

18-16. There will also be occasions when you find the material will bend excessively or will bend further on one side of the brake than on the other. To correct this condition, set the top leaf back on the end where the sheet is over bending.

18-17. If the bending leaf becomes bowed after heavy use, tighten both bolts Z until the center is brought into line. This line should be a straight line; check it with a straightedge.

18-18. *Formers.* Molds or formers can be obtained in half-round sizes such as ⅝, 1, 1⅝, 2¼, and 3 inches. They are used most often to make gutters. These formers are attached to the cornice brake by means of clamps. When attaching the formers to the brake, there should be ½-inch clearance on the side of the formers against the bending leaf. Position the clamps vertically to the ground and tap lightly with a mallet. This creates enough friction to hold the formers in place. When the need arises to remove the clamps, tap upward with a mallet.

18-19. **Box and Pan Brake.** The construction of the box and pan brake is a great deal like that of a cornice brake except that the clamping leaf is divided into sections called fingers or shoes. These fingers vary in width and are all interchangeable. This machine, illustrated in figure 103, is especially designed for making boxes of various sizes and shapes, as it permits the forming of all sides without distorting any of the finished bends. If the need arises, this brake can be used to do any work that can be done on a standard cornice brake.

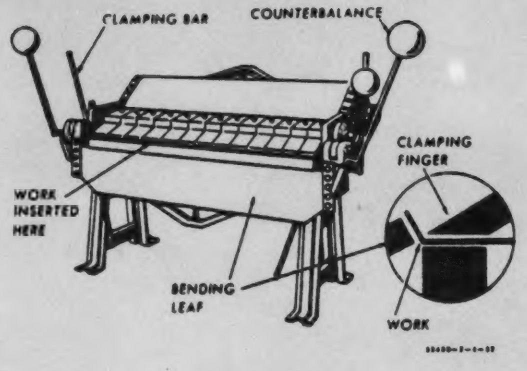


Figure 103. Box and pan brake.

18-20. If the brake should need adjustment, since it is a great deal like the cornice brake, all adjustments (such as radium and thickness) can be accomplished by the same procedures as with the cornice brake. The steel fingers are secured to the upper beam by means of thumbscrews. The fingers must be securely seated and the thumbscrews tightened before using the brake. To remove any of the fingers, simply loosen the thumbscrews, raise the clamping fingers by pushing the clamping bar backward, and then pull the finger forward. When installing the fingers, reverse this procedure.

18-21. Before you start any work on the box and pan brake, be sure all the adjustments are made for the gage of metal you are using. Do not bend rod, wire, band iron, or spring-tempered sheets on either the box and pan or cornice brakes.

18-22. **Hand-Operated Slip Roll Forming Machine.** The slip roll forming machine, illustrated in figure 104, is used to form sheets into cylinders of various diameters and to form permanent

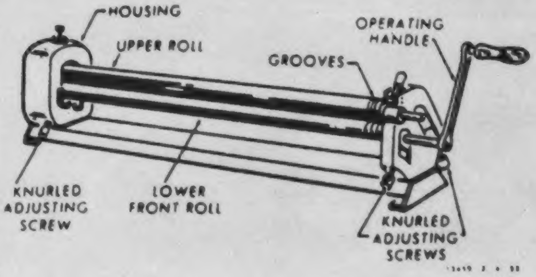


Figure 104. Hand-operated slip roll forming machine.

18-30. Maintenance is about the same for hand-operated and power slip roll machines—lubricating the moving parts, keeping the rollers clean, and keeping the machines clear at all times. When the rollers get dirty, clean them with steel wool and a dry rag; then wipe them with an oiled rag to prevent corrosion.

18-31. You should observe safety precautions, such as keeping your hands, fingers, and clothing clear of the rollers and drive gears, at all times. As with other machines, handle metal carefully to keep burrs from cutting your hands. Never apply power to the rolls until you are certain the machine is clear. If you are working on large jobs that require assistance from another worker, make certain that you both are qualified operators and that you understand which part of the operation each will perform.

18-32. **Rotary Machines.** The rotary machines illustrated in figures 106 through 112 are designed to rotate various shapes of matched roll dies which press sheet stock into desired shapes. Sheet stock is fed between these rolls in a similar manner to that for slip roll formers. Basically, a rotary machine consists of two shafts mounted in a frame. These rolls are mounted on one end of the shafts, and a pair of mesh gears and a handle (or pulley) is mounted on the other. The distance between the two rolls can be adjusted by a small crank located on top of the machine. Rotary machines are manufactured to operate either by power or by hand and, like many others, are equipped with gages to guide the metal. Such gages can be set to determine the depth at which a sheet passes between the rolls. Most rotary machines have a head position adjustment and lockscrew, as shown in figure 106.

18-33. Because some rotary machines are designed for one specific operation, the operator must be certain of what each machine can do. This will be easy for you, since the name of each rotary machine, in most cases, defines the job that it does. Typical examples are burring, turning, elbow edging, setting down, crimping, and beading machines.

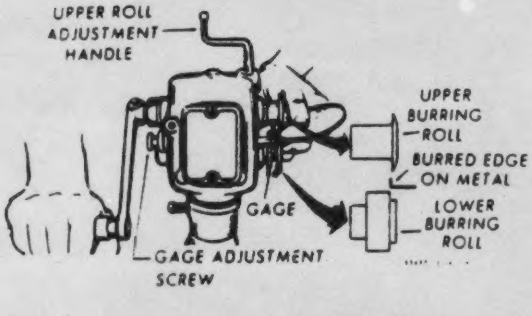


Figure 107. Rotary burring machine.

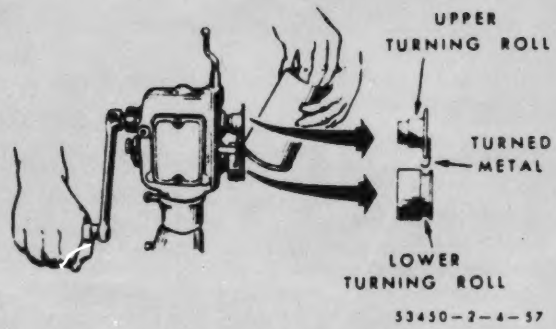


Figure 108. Turning machine.

18-34. The rotary machine illustrated in figure 106 is a combination of several rotary machines. By changing dies, this machine can perform several operations. This machine has a combination rotary head that will accept turning rolls, burring rolls, and wiring rolls. To change these rolls, loosen the nuts on the end of the shafts and remove the rolls and replace them with rolls that are desired. Some of the nuts have left-hand threads; therefore, you should be careful when changing the rolls.

18-35. *Rotary burring machine.* A burring machine, such as that shown in figure 107, is used to turn flanges and edges on circular discs and cylinders. It is also used for turning edges on elbows and for making double seams and single hems when other machines are not available. An important thing to remember is that it takes considerable time, effort, patience, and practice to turn out a good job.

18-36. To operate the rotary burring machine, you must adjust and align it so that the side edge of the top roll protrudes over the shoulder of the bottom roll twice the thickness of the metal. The opening between the rolls should be equal to the thickness of the metal. Be sure these adjustments are correct because if the opening is too small, the top roll will act as a shear and cut the metal. The gage adjustment screw that controls the amount of metal turned up (flanged) is on the back of the machine. Flange limits are from 1/8 to 1/4 inch.

18-37. To start the forming operation, place the disc in the machine and lower the top roll with the crank screw until the machine grips the metal and creases it slightly. Turn the crank slowly in a clockwise direction while keeping the edge of the disc firmly against the gage. Use caution to prevent injury to your hand when the disc is rotating between the thumb and forefinger.

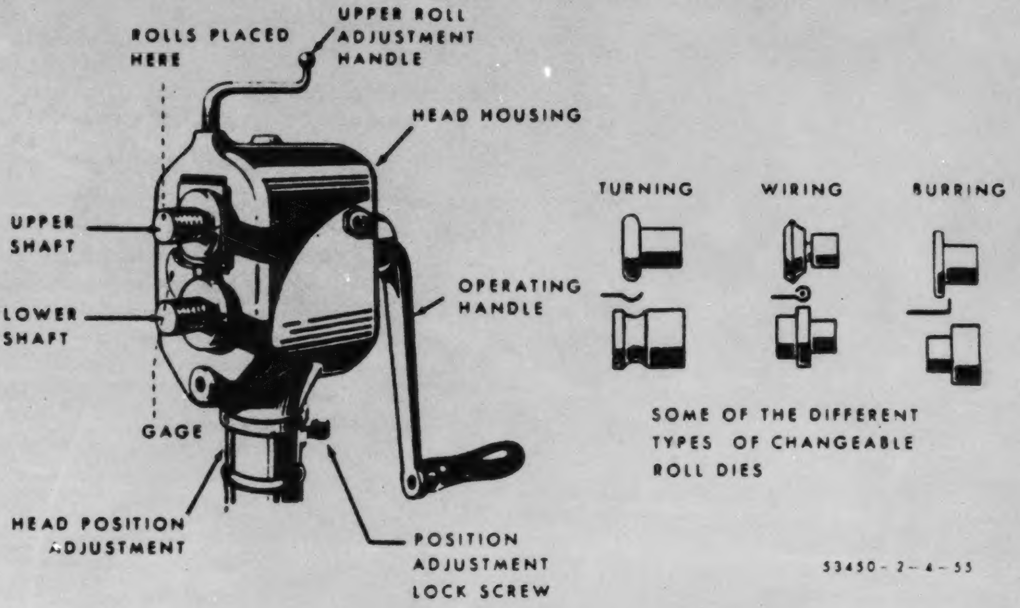


Figure 106. Rotary machine.

the adjusting screws, set the lower rear roll for the desired radius. This adjustment must be the same on both ends to form cylinders unless a taper is desired. A truncated cone or frustum is formed when the screws have different adjustments. When the rolling process is completed, release and raise the upper roll. Then remove the test piece and make final adjustments. Place the material square with the rolls, and turn the crank clockwise. The cylinder that is formed should be the finished product. No change of adjustments on the machine will be necessary if more than one item of the same size is to be formed.

18-25. **Power-Operated Slip Roll Forming Machine.** The power-operated slip roll forming machine, shown in figure 105, is a great deal like the hand-operated slip roll machine in that it has two lower rolls and one upper roll. However, turning power for the rolls is supplied by an electric motor. Direction of the rolls is controlled with a reversing switch.

18-26. The power-operated slip roll machine, like the hand-operated version, has a limitation as to the diameter (radius) it can produce. When the machine is operating at maximum capacity (thickness and size of the sheet stock), the diameter of the cylinder formed should not be less than two times the diameter of the upper roll. If this recommendation is not followed, the formed cylinder will have flat spots at the seam.

18-27. The front gripping rolls can be adjusted for clearance (according to the thickness of metal to be formed) by turning screw handles located under the ends of the lower front roll. The lower rear roll can be adjusted for radius of bend by moving the endless chain. This chain turns adjustment screws at each end of the machine to keep the lower rear roll parallel with the gripping rolls. After the cylinder is formed, it can be removed by releasing the upper roll locking handle and pressing down on the raising lever located at the right-hand end of the machine.

18-28. Before starting the electric motor, you must press the ON button of the ON-OFF switch. Then move the reversing switch lever from the OFF position to the FORWARD position. This starts the motor and sets the rolls in motion for normal operation. When it is necessary to reverse the direction of the rolls, move the reverse switch lever to the OFF position until the rolls stop rotating; then move the lever to the REVERSE position. When a job has been completed, stop the rolls and remove power by moving the reverse switch lever to the OFF position and by pressing the OFF button of the ON-OFF switch.

18-29. Operation of the power slip roll machine is similar to that of the smaller, hand-operated slip roll except that heavier gage metal can be formed. The heavier gages must be inserted and rolled for 7 to 9 inches, then backed out, turned around, and rolled from the other end in the regular way. This is done to prevent a flat spot along the seam.

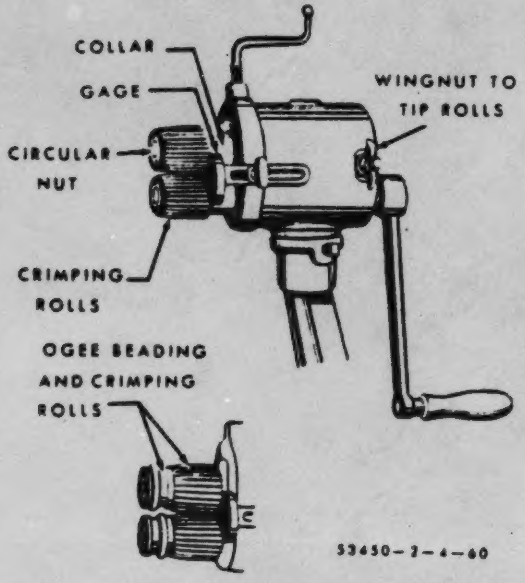


Figure 111. Crimping machine.

perpendicular to the lower roll, and the other has both rolls sloping toward the machine.

18-46. When double-seaming the bottom of a can or tank, hold the object in any convenient position, and run it between the rolls. The crank screw on top of the machine can be adjusted to any pressure necessary to close the seam.

18-47. Machine operation consists of placing the object between the upper and lower rolls and lowering the top roll. Medium pressure is desirable for the first revolution around the bottom of the object and should be continued until all wrinkles are removed. After this setting down operation has been completed, the seam must be turned up tight against the side with a mallet and stake or double-seaming machine.

18-48. *Crimping machine*. The crimping machine, shown in figure 111, is used to make one end of a pipe joint smaller than the other so that the two sections may be slipped together. Some of the crimping machines have combination bending rolls and crimping rolls. The bead serves to reinforce a formed cylinder and to prevent the crimped edge from slipping too far into the other cylinder.

18-49. The mechanism is similar to that of most rotary machines. For jobs with riveted or grooved seams, the crimp is started near one side of the seam and run around the cylinder to the other side of the seam. Never crimp a seam, because its thickness will damage the rolls and spring the shafts of the machine.

18-50. When a tube or object is to be crimped, it is inserted between the rolls and the gage is adjusted to the correct width of the crimp desired. The top roll is lowered until it makes a slight depression in the tube as the operating handle is turned. This operation is repeated until the desired fit is obtained.

18-51. *Beading machine*. The beading machine, shown in figure 112, is used for making beads in sheet metal objects such as cans, buckets, and tubing. Beads act as stiffeners and serve as stops for connecting two or more lengths of metal tubing. The beading machine is easy to operate; with practice, you can turn out high-quality work. It comes equipped with several pairs of rolls which can be removed and replaced in the same manner as the burring and wiring machine rolls. The beading machine rolls that are generally used are single rolls, double rolls, triple rolls, and ogee rolls.

18-52. To operate the beading machine, place the cylinder between the rolls so that the top roll is on the outside of the cylinder. Place the edge of the cylinder against the adjustable guide (gage), and keep it there at all times or the beads will not meet after the first revolution. The adjustable guide can be set at different locations so that one or more beads can be made at different distances from the edge. Next, lower the rolls with the crank screw until a slight depression is made in the metal. Turn the handcrank with the right hand as the work is guided with the left; as the work revolves around the rolls, an impression is completed. Do not run the rolls over a seam, because that will damage the machine and weaken the seam.

18-53. **Power Flanging Machine.** The power-operated flanging machine, illustrated in figure 113, is designed for forming many different kinds of flanges and hems from flat or irregular shaped sheet metal. Sheet metal stock up to 10-gage mild steel can be formed on this machine. Special dies are furnished with the machine, each designed for a special radius or shape.

18-54. You should observe these procedures in preparing to use this machine:

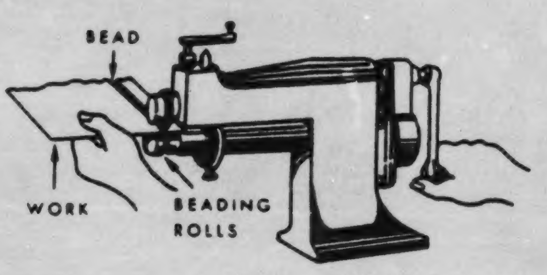


Figure 112. Beading machine.

The first revolution of the rolls should be slow enough to permit accurate starting of the burred edges. After the first revolution of the disc, it is possible to disregard the gage and follow the crease as the top pressure increases. Continue turning as before. Raise the disc slightly after each revolution until the full burred edge has been formed.

18-38. *Turning machine*. The turning machine, illustrated in figure 108, is used to form rounded flanges for wired edges. The rolls of this machine may also be used to turn double seams on elbows when an elbow edging machine is not available. The turning rolls are removable; thin turning rolls are available for light work, and thick rolls are used for heavy work.

18-39. The first operation is to center the top and bottom rolls, then adjust the gage so that it allows ample space for the wire. When the gage has been properly set, rest the cylinder to be wired on the lower roll, and press the edge against the gage. With the cylinder in place, lower the upper roll by turning the small crank-screw, located on the top of the machine, until a slight depression is formed in the metal. Turn the crank handle slowly until the cylinder has passed completely through the machine. Be sure to hold the metal firmly against the gage. After the first crease has been made, lower the upper roll and pass the metal through the machine again with the work tilted upward. This process should be repeated several times to obtain the desired groove.

18-40. *Elbow edging machine*. The elbow machine, shown in figure 109, has elbow edging rolls that fit most standard makes of turning and burring machines. The upper roll of the elbow edging machine is V-grooved and has a matching lower roll. The rolls are made in three standard types to permit the fabrication of interlocking edges used in fastening various pieces of elbows together.

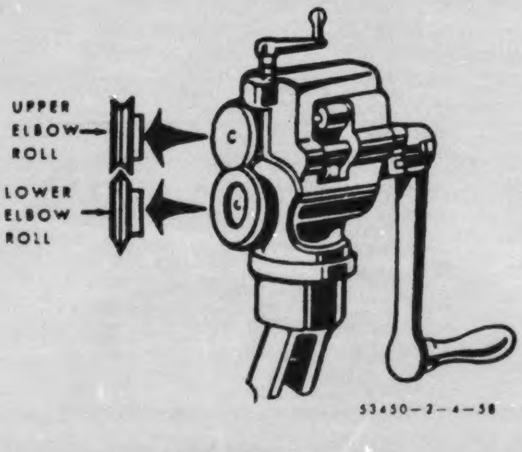


Figure 109. Elbow edging machine.

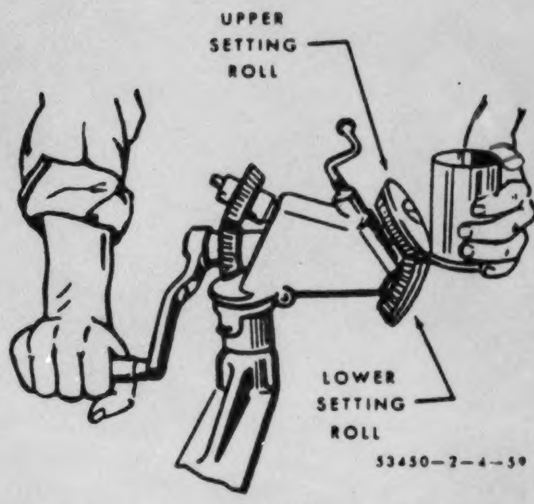


Figure 110. Setting down machine.

18-41. For making various types of edges, the operation is much the same. First, you must determine what lock seam is best suited for the job; then screw the bar (gage) away from the rolls until the desired seam allowance has been made. If use of a guide bar is not practical, draw or scribe a line around the outside of the elbow section ⅛ inch from the edge to be joined. Make a similar line on the matching section inside the cylinder.

18-42. Place the first piece in the elbow edging machine so that the inside surface of the elbow will rest on the lower roll. Keep the edge of the elbow snug against the guide bar, and tighten the top roll until it forms a slight crease in the metal. Turn the handle slowly as you carefully guide the piece through. After one complete revolution of the elbow, tighten the top roll slightly and repeat the process until a deep groove has been made around the edge of the elbow section.

18-43. The second piece is made in the same manner; however, the upper roll is placed on the inside of the cylinder.

18-44. Once the job has been completed, the lock should snap together with very little, if any, difficulty. If the flanges are too loose, they can be tightened with a hammer and stake.

18-45. *Setting down machine*. The setting down machine, shown in figure 110, is used for tightening or setting down the edges prior to double seaming. Two styles of setting down machines are available—one has the upper roll figure 114, is a compact floor base unit, operated through the actuation of a pendulum movement foot pedal. A calibrated handwheel adjustment insures exact grippage for all thicknesses of material within the capacity of this machine. By interchanging the jaw assemblies, this machine can be converted from a shrinker to a stretcher or vice versa.

18-58. This foot-operated machine weighs approximately 400 pounds and when it in use it has a tendency to move across the floor unless it has been bolted down through the floor. Insure that when the machine is not being used, the foot lever retaining lock is installed to prevent accidents caused by tripping over the foot lever. To release the foot lever from the locked position, depress the pedal and push the locking lever toward the rear of the machine, then allow the foot lever to swing to its neutral position.

18-59. It is a simple matter to adjust the jaws for material thickness if you follow these steps:

a. Turn the handwheel counterclockwise, opening the jaw grip to its maximum.

b. Depress the foot lever to its full stroke.

c. Insert the workpiece between the jaws.

d. Turn the handwheel clockwise, until the jaws are snug against the workpiece.

e. Release the foot lever and turn the handwheel clockwise one-quarter turn. The machine is now ready for operation.

18-60. To accomplish the required stretching, a series of local upsets or elongated areas must be formed; therefore, do not apply repeated strokes to one spot. For most effective working, enter the workpiece to about the centerline of the jaws, and feed the work through the machine in equal distances for each stroke of the jaws.

18-61. To insure proper operation of the jaws they must be kept clean of excessive amounts of grease and metal which will adhere to the gripping portion of the jaws, especially clad material. Light oil or kerosene on the workpiece of metal has the tendency to pump the metal particles out of the jaws' surfaces. Periodically remove the jaws and jaw blocks from the machine, dissassemble and clean them of grease and metal deposits. After cleaning, reassemble the parts and grease them prior to reinstallation on the machines.

18-62. **Arbor Press.** The arbor press is not really a forming tool in the normal sense of the word; however, since it is used by the airframe repairman for forming metal, we will include it in this section. In addition to the hand-operated type, hydraulic presses are often used to form aircraft parts from sheet metal stock. They are capable of developing many tons of pressure. The hand arbor press is really a very simple machine. It is used to apply constant pressure to form flanges around holes, as well as to press bushings and other objects requiring a tight fit, where scarring or marring frequently associated with hammers and other driving tools is not allowed.

18-63. The arbor press consists of a ram held in a frame and actuated by applying pressure, or force, on the ram by the use of a lever. The lever is connected to the ram by a pinion gear. The force applied to the lever is transmitted through the pinion gear to a rack on the back of the ram.

18-64. Using the arbor press is a simple task, limited only to the dies available. Insert the proper size and shape of female die on the table which serves as the base for the arbor press. Insure that the material to be formed is free of all nicks and scratches which could cause the material to crack or fail. Then insert the metal between the male and female dies and apply a slow constant pressure with the ram pressing on the male die until the desired shape has conformed to the shape of the female die.

18-65. Now turn to the workbook and answer questions for Section 18.

19. Hand Forming

19-1. Before a part is attached to an aircraft during either manufacture or repair, it has to be shaped to fit into place. This shaping, called forming, may be a very simple process, such as making one or two holes for attaching, or it may be exceedingly complex, requiring shapes of complex curvature.

19-2. In the previous sections of this chapter we have discussed many of the tools and much of the equipment you need to form many of the parts required for aircraft. In this section we will concern ourselves with hand forming and the necessary tools to do a proper job of hand forming. Hand forming is of major concern to you as an airframe repairman and requires the best of your knowledge and skills. This is especially true since hand forming usually involves the use of extremely light-gage alloys of a delicate nature which can be readily made useless by course and careless workmanship. In forming, use hammers and mallets as sparingly as practicable and make straight line bends on bar folders or cornice brakes.

19-3. **Hammers and Mallets.** Sheet metalworking hammers are made of metal. They are used for riveting, setting, stretching, and planishing, and are classified by usage. Mallets are made of hardwood, rubber, plastic, or rawhide; they may be classified as plain-faced and stretching. They are generally used for pounding down seams or

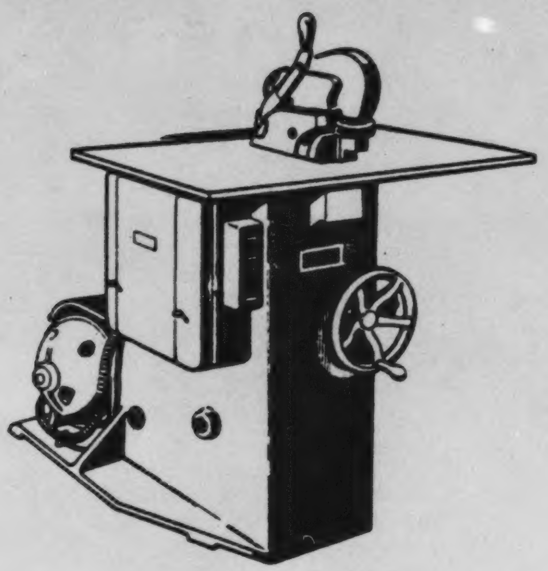


Figure 113. Power flanging machine.

a. Determine the size, type of flange, and the gage of repair material; select the correct holddown tool, brake tool, and spacers for the flange to be formed; raise the brakehead by pushing the trip lever backwards; install the spacers, brake tool, and holddown tool.

b. Lower the brakehead by pulling the trip handle lever forward; move the flywheel so that the brakehead is in the lowest position; adjust the holddown tool for the thickness of metal being formed. Place the metal between the holddown tool and the table. Make the correction for thickness with the vertical adjustment.

c. Remove the metal and turn the handwheel so that the brake tool will be in the vertical position; adjust the clearance for the flanges by using the horizontal adjustment. Check the adjustments to see that the parts are not binding. Turn the flywheel by hand.

d. Use the handwheel to lower the brake tool to the lowest position; raise the brakehead and insert the metal under the holddown tool. The edge of the metal should touch the finger guide. Oil may be used to lubricate the metal for ease in movement.

e. Lower the brakehead with the trip lever and revolve the flywheel to check the machine.

18-55. Start the machine at a slow speed and turn the handwheel until the braketool bends the flange approximately 30°. Slowly move the metal back and forth under the holddown tool, keeping the contoured edge against the finger guide until the entire flange starts forming.

CAUTION: Keep your fingers away from the holddown and brake tools while the machine is operating.

18-56. During operation of the flanging machine raise the brake-tool screws, as they have a tendency to work loose while the machine is in operation. After the flange is bent approximately 60°, stop the machine and change to a higher speed if you desire. When the flange is formed, lower the brake tool to the lowest position and stop the machine. Raise the brakehead and remove the work.

18-57. **Stretching and Shrinking Machine.** The stretching and shrinking machine, illustrated in

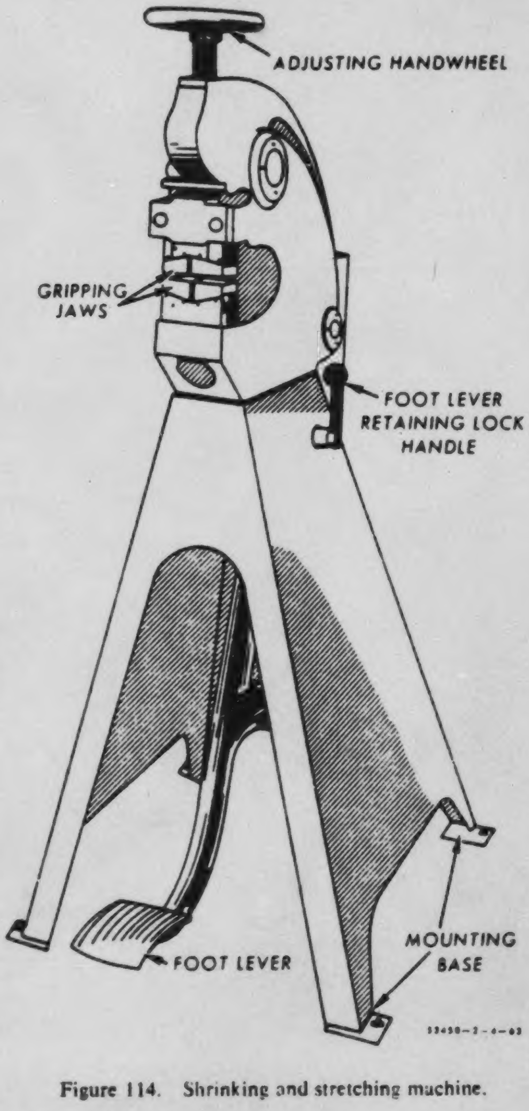


Figure 114. Shrinking and stretching machine.

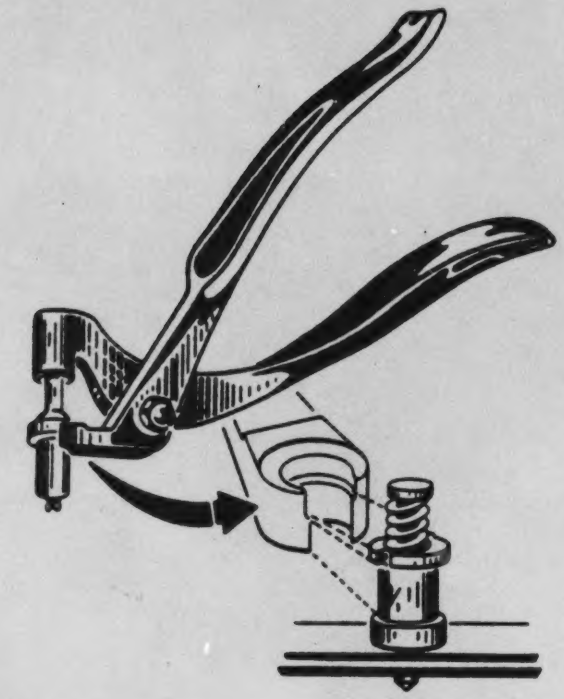


Figure 116. Cleco fastener.

19-17. **Holding Devices.** Vises and clamps are tools used for holding materials of various kinds on which some type of operation is being performed. The type of operation and the type of metal being used determine the holding device to use.

19-18. *Vises.* The most commonly used types of vises are shown in figure 115. The machinist's vise has flat jaws and usually a swivel base, whereas the utility bench vise has scored, removable jaws and an anvil faced back jaw. This vise will hold heavier material than the machinist's vise and will also grip pipe or rod firmly. The back jaw can be used for an anvil if the work being done is light.

19-19. *C-clamps.* The carriage clamp, or C-clamp as it is commonly called, is shaped like a large "C" and has three main parts—the threaded screw, the jaw, and the swivel head. The swivel plate, which is the bottom of the screw, prevents the end from turning directly against the material being clamped. C-clamps vary in size from 2 inches upward, and their function is always that of clamping or holding.

19-20. The shape of the C-clamp allows it to span obstructions near the edge of a piece of work. The greatest limitation in the use of the carriage clamp is its tendency to spring out of shape. It should never be tightened more than hand tight.

19-21. *Sheet metal holders.* The most commonly used sheet metal holder is the Cleco fastener. It is used to keep drilled parts made from sheet stock pressed tightly together. Parts that are not held tightly together will separate while being riveted.

19-22. This type of fastener is available in six different sizes: $\frac{3}{32}$, $\frac{1}{8}$, $\frac{5}{32}$, $\frac{3}{16}$, $\frac{1}{4}$ and $\frac{3}{8}$ inch. The size is stamped on the fastener and if the size marking is missing the fastener may be identified by its color. Notice in figure 116 how a Cleco fastener is used to hold two sheets of metal together. Special pliers are used to insert and remove the Cleco in a drilled hole. One pair of pliers will fit the six different sizes.

19-23. Sheet metal screws are sometimes used as temporary holders. The metal sheets must be held tightly together before you install these screws, as the self-tapping action of the threads tends to force the sheets apart. Place washers

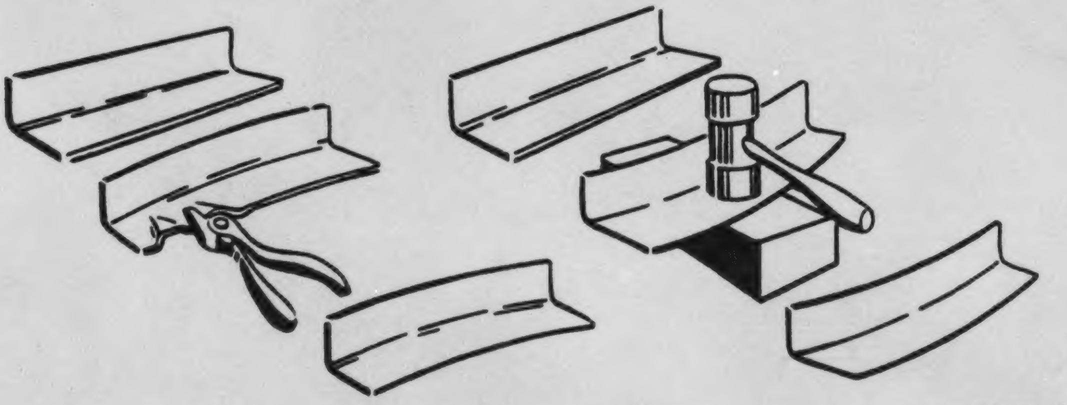


Figure 117. Crimping and stretching.

forming sheet metal over forms or stakes. Since they do not dent or mar the metal as steel hammers do, they are often used for finishing.

19-4. *Riveting hammer.* Riveting hammers are for driving rivets and light chiseling. One end of the hammer head is crosspeened (crosspointed), and the other may have either a square or a chamfered face. Sizes range from ⅝ inch to ⅛ inch, measured across the face.

19-5. *Setting hammer.* Setting or peening hammers resemble riveting hammers except in the shape of the peen (the pointed end). These hammers are used for setting down, clinching, or tucking in the edges of sheet metal. They are particularly useful for double-seaming lids and bottoms and for making seams and elbows. Setting hammers are made with either square faces or chamfered faces. Chamfered face types are preferred.

19-6. *Stretching hammer.* Stretching hammers, also called raising hammers, are for making small depressions or forming concave and convex shapes in soft and semisoft sheet metal. They are available in weights ranging from 20 to 90 ounces.

19-7. *Planishing hammer.* Planishing hammers have metal heads with slightly convex faces. They are lighter than stretching hammers, and are used primarily to smooth (or planish) the surface of parts which have already been formed. In many cases, the flatface wooden, plastic, or rawhide mallet is used for planishing. In planishing, place the metal on a smooth surface, such as a forming block or stake, and lightly strike the irregularities with the face of the hammer.

19-8. *Mallets.* Plain-faced mallets are all-purpose mallets. They are usually made of hardwood or rawhide and both faces are plain. During the forming process, they are best suited for planishing—that is, for finishing or removing the remaining small dents and crimps. Stretching mallets may be made of plastic, hardwood, or hard rubber.

19-9. The bellshaped, the round, and the crosspeen ends are for stretching (or for shrinking), and the plain-faced ends for planishing. The bellshaped and round-faced mallets are handy for bumping aluminum into form blocks or on a sandbag.

19-10. Always keep the faces of hammers and mallets smooth and free dents to prevent marring the metal while working on it.

19-11. **Pliers.** There are several types of pliers. Those used most frequently in airframe repair work are the side-cutting, adjustable combination, flatnose, roundnose, and half-roundnose pliers. The size of pliers indicates their overall length, usually ranging from 5 to 12 inches. In addition to the 6-inch size, it is a good idea to have 5-inch pliers for light work and 10-pliers for light work and 10-inch pliers for heavy work. The better grades of combination pliers are drop forged steel. These adjustable combination pliers are used principally for holding and bending flat or round stock.

19-12. *Flatnose pliers.* Flatnose pliers are very satisfactory for making flanges. The jaws are square, fairly deep, and usually well matched. The hinge is firm. These characteristics serve to give a sharp, neat bend.

19-13. *Roundnose pliers.* These pliers are used to crimp metal. They are not made for heavy work because too much pressure will spring the jaws, which are often wrapped to prevent scarring the metal.

19-14. *Half-roundnose pliers.* These pliers have half-round jaws of varying lengths. They are used to hold objects and to make adjustments in tight places.

19-15. *Diagonal cutting pliers.* These pliers are usually referred to as diagonals or "dikes." The diagonal is a short-jawed cutter with a blade set a slight angle on each jaw. This tool can be used to cut wire, rivets, small screws, and cotter pins, besides being practically indispensable in removing or applying safety wire.

19-16. *Crimping pliers.* These pliers have practically the same design as the ordinary roundnose pliers. Since a crimp is made by twisting rather than by clamping, crimping pliers are constructed of heavier material to withstand the heavy side load caused by the twisting action. It is a sound procedure to keep the points of the pliers covered with adhesive tape or similar material to avoid scratching or marring the metal.

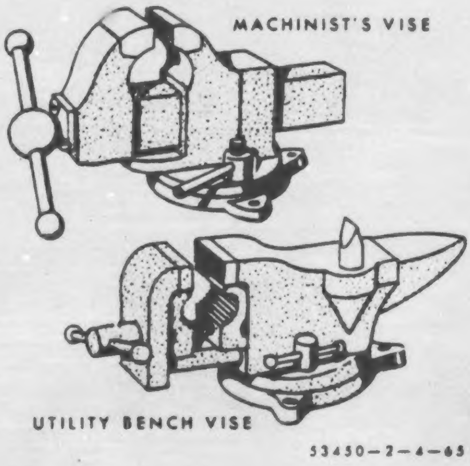
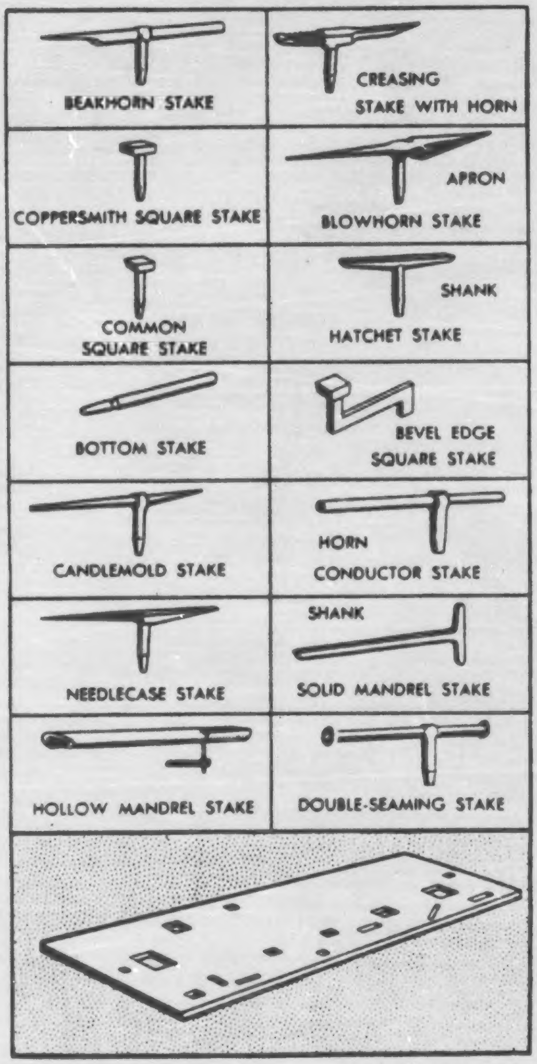


Figure 115. Vises.

19-36. ***Shrinking.*** During the shrinking process, material is forced or compressed into a smaller area. The shrinking process is used when the length of a piece of metal, especially on the inside of a bend, is to be reduced. Sheet metal can be shrunk in two ways: by hammering on a V-block, as illustrated in figure 118, or by crimping and then shrinking on a shrinking block.

19-37. To curve the formed angle by the V-block method, place the angle on the V-block and gently hammer downward against the upper edge directly over the V. Move the angle back and forth across the V-block while hammering, to compress the material along the upper edge. Compression of the material along the upper edge of the vertical flange will cause the formed angle to take on a curved shape. The material in the horizontal flange will merely bend down at the center and the length of that flange will remain the same. This method is effective if the curve (or the bend) is not to be too sharp.



53450-2-4-69

Figure 119. Bench plate and stakes.

19-38. To make a sharp curve or a sharply bent flanged angle, you would probably use crimping and a shrinking block. In this process, you would place crimps in the one flange, then apply a shrinking block and, by hammering, drive out (shrink out) the crimps one at a time.

19-39. **Dollies and Stakes.** Sheet metal is often formed or finished (planished) over various shaped anvils called dollies and stakes. These are used for forming small, odd-shaped parts, or for putting on finishing touches, for which a large machine may not be suited. Dollies are meant to be held in the hand, whereas stakes are designed to be supported by a flat cast iron bench plate fastened to the workbench. (See fig. 119.)

19-40. Most stakes have machined, polished surfaces which have been hardened. Do not use stakes to back up material when chiseling, or when using any similar cutting tool, as this defaces the surface of the stake and makes it useless for finish work.

19-41. *Square stakes.* Three types of square stakes—the common square stake, the coppersmith square stake, and the bevel-edge square stake—are for general sheet metalwork. The coppersmith stake has one rounded end while the bevel-edge stake is offset, permitting a greater variety of applications.

19-42. *Double-seaming stake (simple).* The double-seaming stake has two horns with elongated heads. It is used as a support when laying down double seams on small cylindrical objects.

19-43. *Roundhead stake.* The roundhead stake is not used extensively. However, its curved head makes it quite suitable for forming curved and irregularly shaped objects.

19-44. *Bottom stake.* The bottom stake has a flared end and is used for dressing down an object having a burred or flanged circular bottom.

19-45. *Needle case stake.* The needle case stake has a round, tapered horn for forming small rings and tubular objects, and a heavier rectangular horn on which square work can be formed.

19-46. *Conductor stake.* The conductor stake has two cylindrical horns of different diameters. It is for forming, seaming, and riveting pipes and elbows, especially those with small diameters.

19-47. *Candle mold stake.* The candle mold stake has a horn of rather large diameter on one end and a long, tapered horn at the other. The under the heads of the screws to keep them from marring or scratching the metal.

19-24. **V-Blocks.** V-blocks made of hardwood are widely used in airframe metalwork for shrinking and stretching metal, particularly formed and extruded type of angles and flanges that must be curved (not bent at sharp angles). The size of the block depends on the work being done and on personal preference. Although any type of hardwood is suitable, maple and ash are recommended for best results when working with aluminum alloys.

19-25. **Hardwood Form Blocks.** Hardwood form blocks can be constructed to duplicate practically any aircraft structural or nonstructural part. The wooden block or form is shaped to the exact dimensions and contour of the part to be formed.

19-26. When shaping the blocks, do the rough work with ordinary wood saws, chisels, gouges files, and rasps, and do the final smoothing with sandpaper. Since the form must be accurate, prepare several templates so that you can test the accuracy of the form at frequent intervals. If the forms are to be used over a period of time, apply several coats of shellac to the blocks to keep them from checking, cracking, or shrinking.

19-27. **Shrinking Blocks.** A shrinking block consists of two metal blocks and some device for clamping them together. One block forms the base and the other is cut away to provide space where the crimped material can be hammered. The legs of the upper jaw clamp the material to the base block on each side of the crimp so that the material will not creep away but will remain stationary while the crimp is hammered flat (being shrunk). This type of crimping block is designed to be held in a bench vise.

19-28. Shrinking blocks can be made to fit any specific need. The basic form and principle remain the same, even though the blocks may vary considerably in size and shape.

19-29. **Sandbags.** A sandbag is generally used as a support during the bumping process. A serviceable bag can be made by sewing heavy canvas or soft leather to form a bag of the desired size, and filling it with sand that has been sifted through a fine mesh screen.

19-30. Unless a heavy-duty sewing machine is available, sew the bag by hand, using a heavy cord. The seam made by an ordinary sewing machine will not be strong enough. Before filling the big with sand, use a brush to coat the inside of it with heated paraffin or beeswax, which forms a sealing layer and prevents the sand from working through the pores of the canvas.

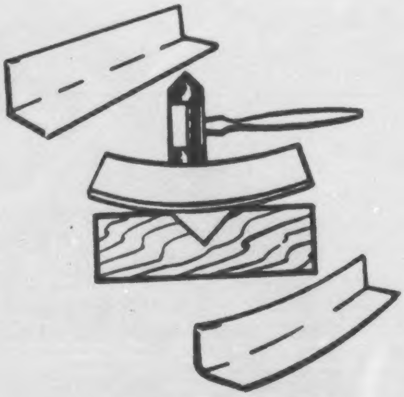
19-31. **Forming Operations and Terms.** The methods you will use in forming operations include such sheet metal processes as shrinking stretching, bumping, crimping, and folding.

19-32. *Bumping*. Shaping or forming malleable metal by hammering or pounding it to form a bump is called bumping. During this process, the metal is supported by a dolly, a sandbag, or a die. Each contains a depression into which hammered portions of the metal can sink. Bumping can be done by hand or machine.

19-33. *Crimping*. Whenever you fold, pleat, or corrugate a piece of sheet metal in a way that shortens it you are crimping it. Crimping is often used to make one end of a piece of stovepipe slightly smaller so that one section may be slipped into another. Turning down a flange on a seam is also called crimping. Crimping one side of a straight piece of aluminum angle with cirmping pliers will cause it to curve, as illustrated in figure 117.

19-34. *Stretching*. If you should hammer a flat piece of metal in an area as is indicated in figure 117, the material in that area will become thinner. However, since the amount of metal will not have been decreased, it will cover a greater area. You will therefore have caused stretching at this spot.

19-35. Stretching one portion of a piece of metal affects the surrounding material, especially in the case of formed and extruded angles. For example, if you should hammer the metal in the horizontal flange of the angle strip over a metal block, as illustrated in figure 117, its length would be increased (stretched); and, therefore, that section would become longer than the section near the bend. To allow for this difference in length, the vertical flange which tends to keep the material near the bend from stretching would be forced away from the greater length.



53450—2—4—68

Figure 118. Shrinking on a V-block.

the aid of a small hardwood block. If any portion of the angle strip is curved too much, reduce it by reversing the angle on the V-block and hammering with a suitable mallet, as previously explained in the paragraphs on stretching. When you have obtained the proper curve, smooth the entire angle by planishing with a soft-faced mallet.

19-62. If the curve in a formed angle is to be quite sharp or if the flanges of the angle are rather broad, the shrinking block method must be used. In this process, crimp the flange which is to form the inside of the curve.

19-63. When making a crimp, hold the crimping pliers so that jaws are about ⅛ inch apart. By rotating the wrist back and forth, bring the upper jaw of the pliers into contact with the flange, first on one side and then on the other side of the lower jaw. Complete the crimp by working a raised position into the flange, gradually increasing the twisting motion of the pliers. Do not make the crimp too large, as it will be difficult to work out. The size of the crimp depends upon the thickness and softness of the material, but usually about ¼ inch is sufficient. Place several crimps spaced evenly along the desired curve with enough space left between each crimp so that jaws of the shrinking block can be easily attached.

19-64. After completing the crimping, place the crimped flange in the shrinking block so that one crimp at a time is located between the jaws. Flatten each crimp with light blows of a soft-faced mallet, starting at the apex (the closed end) of the crimp and gradually working toward the edge of the flange. Check the curve of the angle with the pattern periodically during the forming process and again after all the crimps have been worked out. If it is necessary to increase the curve, add more crimps and repeat the process. Space the additional crimps between the original ones so that the metal will not become unduly work-hardened at any one point. If the curve needs to be increased or decreased slightly at any point, use the V-block.

19-65. After obtaining the desired curve, you may planish the angle strip over a stake or a wooden form.

19-66. **Flanged Angles.** The forming process for the following two flanged angles is slightly more complicated than that just discussed in that the bend is shorter (not gradually curved) and necessitates shrinking or stretching in a small or concentrated area. If the flange is to point toward the inside of the bend, the material must be shrunk. If it is to point toward the outside, it must be stretched.

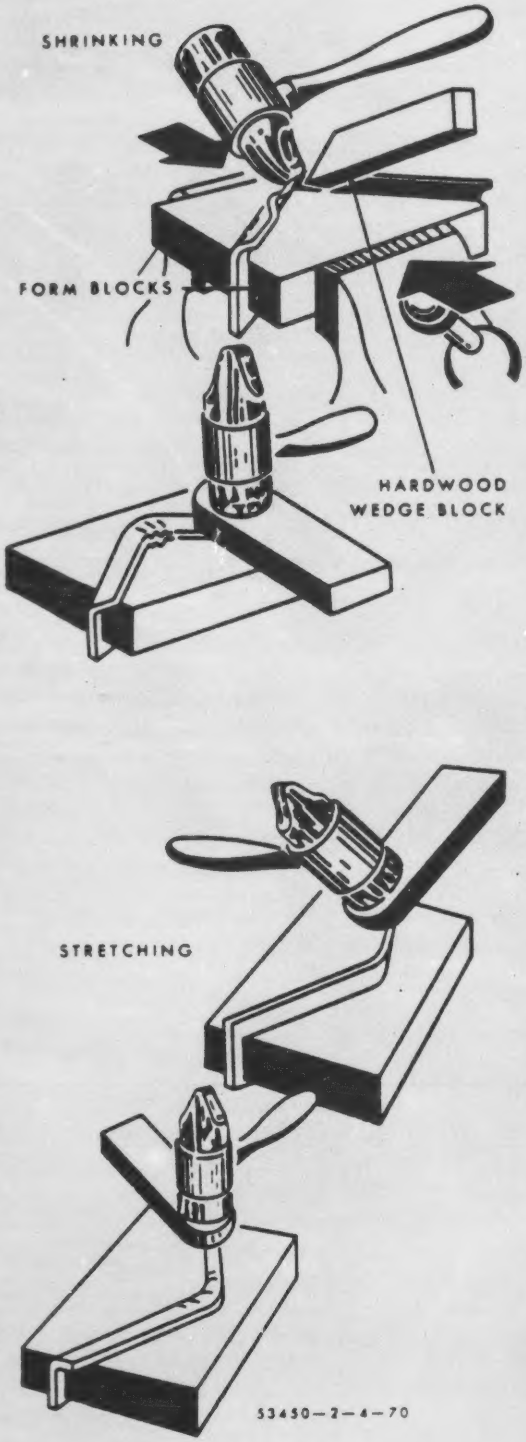


Figure 120. Forming a flanged angle.

larger horn is used for general purposes, and the smaller one is for reshaping and for tube forming.

19-48. *Hatchet stake.* The hatchet stake has a beveled horizontal bar. It is used for making straight bends as well as for folding and bending edges. Flanging and dovetailing may also be done on it.

19-49. *Double-seaming stake (four heads).* This double-seaming stake has two shanks and four interchangeable heads. This arrangement permits it to be used for several different positions and conditions. It is suitable for all kinds of riveting and for double seaming of large objects.

19-50. *Creasing stake.* The creasing stake has a tapered horn on one end for shaping conical objects. A creased mandrel on the other end permits bending, wiring, and turning operations.

19-51. *Beak horn stake.* A round, tapered horn on one end and a square, tapered horn on the other make the beak horn stake adaptable for general sheet metalwork and shaping, and for riveting round and square objects.

19-52. *Blow horn stake.* The blow horn stake has a large, tapered end, called an apron, which is used for shaping objects with abrupt tapers, such as funnels. The other end of the stake is round and has a long, narrow taper for forming slightly tapered objects. It can also be used to form metal or wire into rings of small diameter.

19-53. *Solid mandrel stakes.* Solid mandrel stakes are available in 30-, 34½-, and 40-inch lengths. Each has the double shank on one end. In general, this stake is used for riveting, forming, and seaming square or rectangular material.

19-54. *Hollow mandrel stake.* The hollow mandrel stake has a slot on the lower side in which a large bolt slides, making it possible to fasten the stake securely in any desired position on the bench. This stake comes in overall lengths of either 40 or 60 inches. It has a square section at one end and a rounded mandrel on the other, which makes it suitable for riveting, forming, and seaming.

19-55. **Formed or Extruded Angles.** Both formed and extruded angles can be curved (not bent sharply) by stretching or shrinking either of the flanges. Curving by stretching the one flange is usually preferred, since this process requires only a V-block and a mallet and is very easily accomplished.

19-56. *Stretching one flange.* In the stretching process, place the flange to be stretched in the groove of the V-block. Using a stretching mallet, strike the flange directly over the V-portion with light, even blows and gradually force it downward into the V. A blow that is too heavy will buckle the angle strip. Keep moving the angle strip across the V-block, but always strike the spot directly above the V. Form the curve gradually and evenly by moving the strip slowly back and forth, distributing the hammer blows at equal spaces on the flange.

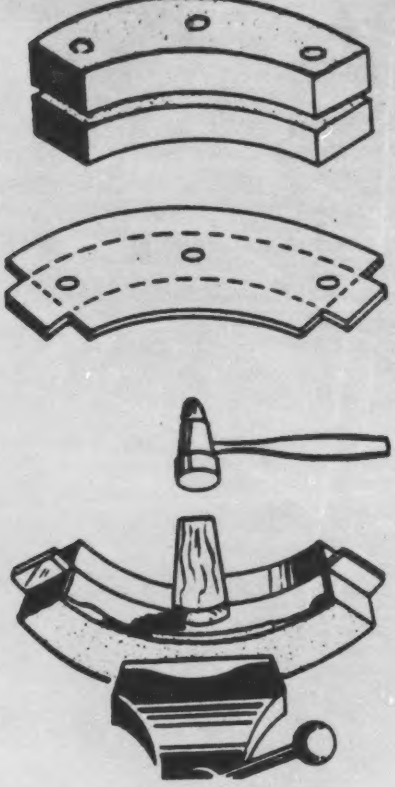
19-57. Lay out a full-sized, accurate pattern on a sheet of paper or plywood and periodically check the accuracy of the curve. By comparing the angle with the pattern, you can tell exactly how the curve is progressing and just where it needs to be increased or decreased. It is better to get the curve to conform roughly to the desired shape before attempting to finish any one portion, because the finishing or smoothing of the angle may cause some other portion of the angle to change shape. If any part of the angle strip is curved too much, reduce the curve by reversing the angle strip on the V-block, placing the bottom flange up, and striking it with light blows of the mallet.

19-58. Try to form the curve with a minimum amount of hammering, for excessive hammering will work-harden the metal. Work-hardening can be recognized by a lack of bending response or by springiness in the metal. It can be recognized very readily by the experienced worker. In some cases, you may have to anneal the part during the curving operation. If you do, be sure to heat-treat the part again before installing it on the aircraft.

19-59. *Shrinking one flange.* Curving an extruded or formed angle strip by shrinking may be accomplished by either of two methods, the V-block method or the shrinking block method. Of the two, the V-block is, in general, more satisfactory because it is faster, easier, and affects the metal less. However, very good results can be obtained by the shrinking block method.

19-60. In the V-block method, place one flange of the angle strip on the V-block with the other flange extending upward, as shown in figure 118. Hold it firmly so that it does not bounce when hammered, and strike the edge of the upper flange with light blows of a round, soft-faced mallet. Begin at one end of the angle strip and, working back and forth, strike light blows directly over the V-portion of the block. Strike the edge of the flange at a slight angle, as this tends to keep the vertical flange from bending outward.

19-61. Occasionally, check the curve for accuracy with the pattern. If a sharp curve is made, the angle (cross section of the formed angle) will close slightly. To avoid such closing of the angle, clamp the angle strip to a hardwood board with the hammered flange facing upward. Use small C-clamps on which the jaws have been covered with masking tape. If the angle has already closed, you can bring the flange back to the correct angle with a few blows of a mallet or with



53450-2-4-72

Figure 122. Forming a concave curve.

with crimps and beads, note that crimps are inserted at equally spaced intervals. The crimps are placed to absorb material and cause curving, and to give strength to the part.

19-73. In the fourth nose rib illustrated, note that all of the four common forming methods are applied. They are crimping, bending, putting in relief holes, and using a formed angle riveted on each end. The beads and formed angles supply strength for the part.

19-74. In forming a curved flange part, cut the material to size (allowing for trim), locate and drill holes for alignment pins, and remove all burrs (jagged edges). Place the material between the wooden blocks. Clamp the blocks tightly in a vise so that the material will not move or shift. Clamp the work as closely as possible to the particular part being hammered, to prevent strain on the form blocks and to keep the metal from slipping. (See fig. 122.)

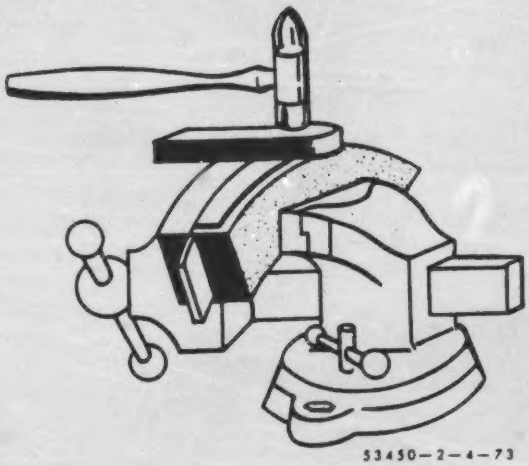
19-75. Bend the flange on the concave curve first. This practice helps keep the flange from splitting open or cracking when the metal is stretched. (Should this occur, a new piece of material will have to be used.) Using a soft mallet or wooden wedge block, start hammering at a point a short distance away from the beginning of the concave bend and continue toward the center of the bend. This procedure permits some of the excess metal along the tapered portion of the flange to be worked into the curve where it will be needed. Continue hammering until the metal is gradually worked down over the entire flange, flush with the form block.

19-76. Starting at the center of the curve and working toward both ends, hammer the convex flange down over the form. (See fig. 123.) Strike the metal with glancing blows, at an angle of approximately 30° off perpendicular, and away with a motion that will tend to pull the part away from the block.

19-77. Stretch the metal around the radius bend and remove the buckles gradually by hammering on a wedge block. While you work the metal down over the form, keep the edges of the flange as nearly perpendicular to the block as possible. The wedge block helps keep the edge of the metal perpendicular to the block, lessens the possibility of buckles and of splitting or cracking the metal, and aids in removing buckles.

19-78. Finally, trim the flanges of excess metal, planish, remove burrs, round the corners (if any), and check the part for accuracy.

19-79. **Bumping.** Bumping on a form block or female die and bumping on a sandbag are the two common methods practices. In either method only one form is required—a wooden block, lead die, or sandbag. A good example of a part made by the block or die type of bumping is the "blister" or streamlined cover plate. Wing fillets are a good example of parts that are usually formed by bumping on a sandbag.



53450-2-4-73

Figure 123. Forming a convex curve.

19-67. *Forming by shrinking*. In forming a flanged angle by shrinking, use wooden form blocks similar to those shown in figure 120 and proceed as follows:

a. Cut the metal to size, allowing for trimming after forming. Determine bend allowance for a 90° bend and round the edge of the forming block accordingly.

b. Clamp the material in the form blocks as shown in figure 120 and bend the exposed flange against the block. After bending, tap the blocks slightly. (This induces a setting process in the bend.)

c. Using a soft-faced shrinking mallet, start hammering near the center and work the flange down gradually toward both ends. The flange will tend to buckle at the bend because the material is made to occupy less space. Work the material into several small buckles instead of one large one, and work each small buckle out gradually by hammering lightly and gradually compressing the material in each buckle. The use of a small hardwood wedge block (as shown in fig. 120) will aid in working out the buckles.

d. Planish the flange after it is flattened against the form block, and remove small irregularities. If the form blocks are made of hardwood, use a metal planishing hammer; if the forms are made of metal, use a soft-faced mallet. Trim the excess material away and file and polish.

19-68. *Forming by stretching*. To form a flanged angle by stretching, use the same forming blocks, wooden wedge block, and mallet as in the shrinking process. Proceed as follows:

a. Cut the material to size (allowing for trim), determine bend allowance for a 90° bend, and round off the edge of the block to conform to the desired radius of bend.

b. Clamp the material in the form blocks as shown in figure 120.

c. Using a soft-faced stretching mallet, start hammering near the ends and work the flange down smoothly and gradually to prevent cracking and splitting. Planish the flange and angle, as in the previous procedure, and trim and smooth the edges, if necessary.

19-69. **Curved Flanged Parts.** Curved flanged parts are usually hand formed. Of the parts shown in figure 121, the one with relief holes is probably the simplest to form. It has a concave flange (the inside flange) and a convex flange (the outside flange).

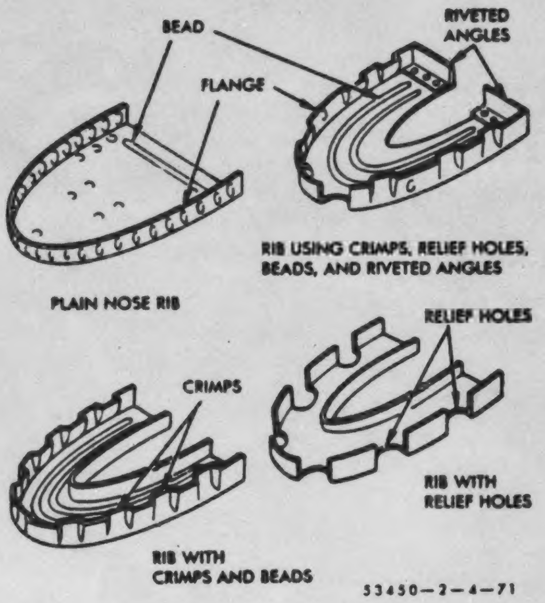


Figure 121. Nose ribs.

19-70. The concave flange is formed by stretching; the convex flange by shrinking. Such parts may be formed with the aid of hardwood or metal forming blocks. These blocks are made in pairs similar to those used for straight angle bends and are identified in the same manner. They differ in that they are made specifically for the particular part to be formed, they fit each other exactly, and they conform to the actual dimensions and contour of the finished article.

19-71. The mating parts may be equipped with aligning pins to aid in lining up the blocks and holding the metal in place. The blocks may be held together by C-clamps or a vise. They also may be held together with bolts by drilling through both forms and the metal, provided the holes do not affect the strength of the finished part. The edges of the forming blocks are rounded to give the correct radius of bend to the part, and are undercut to allow for springback of the metal. The undercut is especially important and necessary if the material is hard or if the bend must be highly accurate.

19-72. Note the various types of forming represented in figure 121. In the plain nose rib, only one large convex flange is used; but, because of the great distance around the part and the likelihood of buckles in forming, it is rather difficult to form. The flange and the beaded portion of this rib provides sufficient strength to make this a very good type to use. In the type with relief holes, the concave flange gives difficulty in forming; however, the outside flange is broken up into smaller sections by relief holes (notches inserted to prevent strains in a bend). In the type drive block and suitable mallet, start the bumping near the edges of the form.

e. With light blows of the mallet, work the material down gradually from the edges. Remember that the object of the bumping process is to work the material into shape by stretching it, rather than by forcing it into the form with heavy blows. Always start bumping near the edge of the form; never start near the center of the blister.

f. Smooth the work as much as possible before removing it from the form. You can do this by rubbing the work with the rounded end of a maple block or with the round end of a stretching mallet.

g. Remove the blister from the bumping block and trim it, leaving a ½-inch flange.

h. Finally, drill the rivet holes, chamfer the edges 45°, and clean and polish the part.

19-88. *Sandbag bumping.* Bumping on a sandbag is one of the most difficult types of sheet metal hand forming, as there is not an exact form block to serve as a guide. During this type of forming operation, you force a depression into a sandbag to take the shape of the hammered portion of the metal. The depression or pit has a slight tendency to shift from the hammering. This necessitates readjusting the pit from time to time during the bumping process. The degree of shifting depends largely on the contour or shape of the piece being formed, and whether glancing blows must be struck in order to stretch, draw, or shrink the metal.

19-89. When forming by this method, prepare a contour template or some sort of pattern to serve as a working guide and to insure accuracy of the finished part. Make the pattern from ordinary kraft or similar paper, folding it over the part to be duplicated. Cut the paper cover at the points where it would have to be stretched to fit, and attach additional pieces of paper with masking tape to cover the exposed portions. After completely covering the part, trim the pattern to exact size.

19-90. Open the pattern and spread it out on the metal from which the part is to be formed. Although the pattern will not lie flat, it will give you a fairly accurate idea of the approximate shape of the metal to be cut, and the pieced-in sections will indicate where the metal is to be stretched. When the pattern has been placed on the material, mark the outline on the part and the portions to be stretched with pencil. Add at least 1 inch of excess metal when cutting the material to size. You can trim off this excess metal after bumping the part into shape.

19-91. If the part to be formed is radially symmetrical, a simple contour template can be used as a working guide. However, the procedure for bumping sheet metal parts on a sandbag follows certain basic rules which can be applied to any part, regardless of its contour or shape.

a. Lay out and cut the contour template. (This can be made of sheet metal, medium-heavy cardboard, or thin plywood.)

b. Determine the amount of metal needed, lay it out, and cut it to size, allowing at least ½-inch excess.

c. Place a sandbag on a solid foundation, capable of supporting heavy blows, and with the aid of a smooth-faced mallet, make a pit in the bag. Analyze the part to determine the correct radius of the pit for the forming operation. The pit will change with the hammering it receives and must be readjusted occasionally.

d. Select a soft round-faced or bell-shaped mallet having a contour slightly smaller than the contour desired on the sheet metal part. Holding one edge of the metal in the left hand, place the portion to be bumped near the edge of the pit on the sandbag. Strike the metal with light glancing blows, about ½ to 1 inch from the edge.

e. Continue bumping toward the center, revolving the metal and working gradually inward until the desired shape is obtained. Shape the entire part as a unit. If you shape one portion completely and continue hammering on some other portion, the completed portion will be thrown out of shape.

f. At frequent intervals during the bumping process, check the part for accuracy of shape by applying the template. If wrinkles are formed, work them out before they become too large.

g. Finally, with a suitable stake and planishing hammer, or with a hand dolly and planishing hammer, remove the small dents and hammer marks.

h. With a pair of dividers, mark around the outside of the object. Trim the edge and file to a smooth finish. Clean and polish the part.

19-92. **Joggling.** A joggle is an offset formed on an angle strip to allow clearance for a sheet or an extrusion. Joggles are often found at the intersection of stringers and formers. One of these members, usually the former, has the flange joggled to fit flush over the flange of the stringer. The amount of offset is usually small; therefore, the depth of the joggle is generally specified in thousandths of an inch. The thickness of the material to be cleared governs the depth of the joggle. In determining the length of the joggle necessary, it is common practice to allow an extra 1/16 inch to give enough added clearance to assure a fit between the joggled, overlapped part.

19-80. ***Form block or die bumping.*** The lead die or the wooden block designed for bumping must have the same dimensions and contour as the outside of the blister. To provide sufficient bucking weight, and to give sufficient bearing surface for fastening the metal, the block or die should be at least 1 inch larger in all dimensions than the form requires.

19-81. When forming the wooden block, hollow it out with saws, chisels, gouges, files, and rasps. Smooth and finish it with sandpaper. Make the inside of the form as smooth as possible, because any slight irregularity will show up on the finished product. Prepare several templates (patterns of the cross section), such as those illustrated with the form block for the blister in figure 124, so that the form can be checked for accuracy.

19-82. Shape the contour of the form at points 2, 3, and 4. Shape the areas between the template checkpoints to conform to the remaining contour and to template 4. Shaping the form block requires particular care, because the more nearly accurate it is in all details, the less time it will take to produce a smooth, finished part.

19-83. Keep in mind that it is important to clamp the material to the form block correctly. Several methods are possible. For parts such as the blister, one of the best means of clamping the material is to use a full metal cutout or steel holddown plate as shown in figure 124.

19-84. In this process, place the holddown plate directly over the material to be formed and clamp it in position with bolts or C-clamps. Tighten the C-clamps or bolts just tight enough to hold the material flat against the face of the form block, but not so tight that the metal cannot be drawn into the form. If the material is not held flat against the face of the form, it will bend up or buckle away from the block. If it is not permitted to slip into the concave depression a little, the blister portion will become very thin in places.

19-85. Holddown plates should be of heavy steel, ⅛ inch for small forms and ¼ inch or heavier for large forms. If the material for making a full metal holddown plate is not available, use a hardwood cutout. Make the cutout and use it in the same manner as the steel plate, but take greater precautions to make sure that the material is held as desired.

19-86. You may use pierced form clamps if a full metal holddown plate or hardwood cutout is not available or if a full cutout cannot be used. Be careful to clamp them properly and locate them so that they line up with the edge of the form. If they are not lined up properly and accurately, the material will bulge.

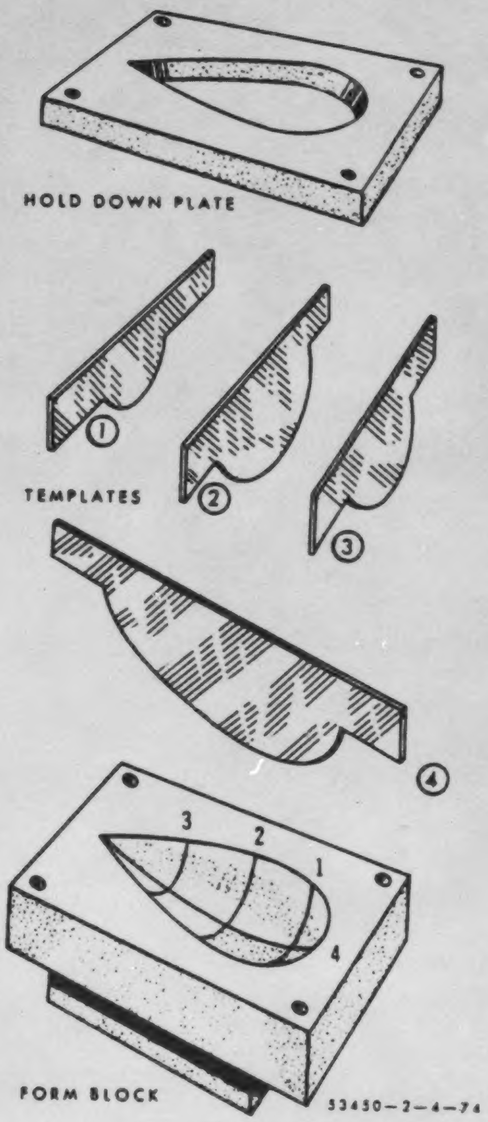


Figure 124. Form blocks and templates.

19-87. After preparing and checking the form, perform the bumping process according to the following general steps:

a. Cut a metal blank to size, allowing an extra ½ to 1 inch to permit "drawing."

b. Apply a thin coat of light oil to the block and to the aluminum to prevent galling (scraping on rough spots).

c. Clamp the material between the block and steel plate, as previously described, so that it will be firmly supported yet able to slip a little toward the inside of the form.

d. Clamp the bumping block in a bench vise. With a soft-faced mallet or with a hardwood

229

19-93. There are a number of different methods by which you can form joggles. If the joggle is to be made on a straight flange or flat piece of metal, form it on a cornice brake by inserting and bending up along the line of the joggle. Hold a piece of metal of the correct thickness to give the desired offset under the bent-up portion, and pound the flange down while the metal is still in the same position in the brake.

19-94. Where a joggle is necessary on a curved flange, forming blocks or dies made of hardwood, steel, or aluminum alloy may be used. If the die is to be used only a few times, hardwood is satisfactory, as it is easily worked. If a number of similar joggles are to be produced, then use steel or aluminum alloy dies. Dies of aluminum alloy are preferred, since they are easier to fabricate than those of steel and will wear about as long. They are sufficiently soft and resilient to permit forming aluminum alloy parts on them without marring; nicks and scratches are easily removed from their surfaces.

19-95. When using joggling dies for the first time, test them for accuracy on a piece of waste stock. In this way you will avoid the possibility of ruining already fabricated parts. Always keep the surfaces of the blocks free from dirt, filings, and the like, so that the work will not be marred.

19-96. Now turn to the workbook and answer questions for Section 19 before going to Section 20.

20. Working Magnesium

20-1. As previously discussed, magnesium in the pure state does not have sufficient strength to be used for structural purposes; but, as an alloy, it has a high strength-to-weight ratio. Its strength is not affected by subzero temperatures, and this increases its adaptability to aircraft use. Its nonmagnetic property makes it valuable for instrument cases and parts.

20-2. While magnesium alloys can usually be fabricated by methods similar to those used on other metals, it must be remembered that many of the details of shop practice cannot be applied. Magnesium alloys are difficult to fabricate at room temperature; therefore, operations other than the most simple ones must be performed at high temperature. This requires preheating of the metal or dies or both.

20-3. Cold-working most magnesium alloys at room temperature is very limited because they work-harden very rapidly and do not lend themselves to any severe cold-forming. Some simple bending operations may be performed on sheet material, but the radius of bend must be at least 7 times the thickness of the sheet for soft material and 12 times the thickness of the sheet for hard material. A radius of 2 or 3 times the thickness of the sheet can be used if the material is heated for the forming operation.

20-4. Wrought magnesium alloys tend to crack after they are cold-worked. Therefore, the best results are obtained if the metal is heated to 450° Fahrenheit before any forming operations are attempted. Parts formed at the lower temperature range are stronger because the higher temperature range has an annealing effect on the metal.

20-5. There are some disadvantages to hot-working. First, heating dies and heating the material is expensive and troublesome. Secondly, there are problems in lubricating and handling materials at these temperatures. However, there are some advantages to hot-working magnesium in that is it more easily formed when hot than other metals and spring-back is reduced, resulting in greater dimensional accuracy.

20-6. When heating magnesium and its alloys, watch the temperature carefully, as this metal is easily burned. Overheating also causes small molten pools to form within the metal. In either case, the metal is ruined. To prevent burning, magnesium must be protected with a sulfur dioxide atmosphere while being heated.

20-7. Proper bending around a short radius requires the removal of sharp corners and burrs near the bend line. Layouts should be made with a carpenter's soft pencil, because any marring of the surface may result in fatigue cracks.

20-8. It is permissible to heat small pieces of magnesium alloy with a blowtorch, provided proper precautions are exercised. It must also be remembered that magnesium will ignite when it is heated to a temperature near its boiling point in the presence of oxygen.

20-9. Press or leaf brakes can be used for making bends with short radii. Die and rubber methods should be used where bends are to be made at right angles, which complicate the use of a brake. Roll-forming may be accomplished cold on equipment designed for aluminum alloys. The most common method of forming and shallow drawing magnesium is an operation in which a rubber pad is used as the female die. This rubber pad is held in an inverted steel pan which is powered by a hydraulic press ram. The press exerts pressure on the metal and bends it to the shape of the male die.

20-10. Now turn to the workbook and complete the exercises for this volume.

☆U. S. GOVERNMENT PRINTING OFFICE: 1974–640-088/264

divided by the common factor 2. Then, with the numerators 1 and 2 and the denominators 5 and 3, you easily arrived at the answer 2/15.

21-15. **Adding Mixed Numbers.** In adding mixed numbers, first add the whole numbers just as in ordinary addition; then add the fractions after changing to common denominators. If the sum of the fractions is an improper fraction, change it to a mixed number or a whole number, add the whole numbers, and keep the remaining fraction as part of the answer.

Examples:

$$\begin{array}{rcl} 12\frac{3}{8} & = & 12\frac{6}{16} \\ 14\frac{3}{4} & = & 14\frac{12}{16} \\ 5\frac{1}{4} & = & 5\frac{4}{16} \\ \hline & & 31\frac{22}{16} \end{array}$$

$$\begin{array}{rcl} 120\frac{3}{4} & = & 120\frac{6}{8} \\ 52\frac{3}{8} & = & 52\frac{3}{8} \\ 23\frac{1}{2} & = & 23\frac{4}{8} \\ \hline & & 195\frac{13}{8} \quad = \frac{13}{8} = 1\frac{5}{8}) \end{array}$$

so

$$195 + 1\frac{5}{8} = 196\frac{5}{8}$$

21-16. **Subtracting Mixed Numbers.** When the fraction in the top number (minuend) is greater than the fraction in the lower number (subtrahend), subtract the whole part from the whole part and the fraction from the fraction.

Examples:

$$\begin{array}{r} 22\frac{4}{5} \\ 12\frac{3}{5} \\ \hline 10\frac{1}{5} \end{array}$$

$$\begin{array}{rcl} 22\frac{3}{4} & = & 22\frac{3}{4} \\ 12\frac{1}{2} & = & 12\frac{2}{4} \\ \hline & & 10\frac{1}{4} \end{array}$$

21-17. If the upper fraction is the smaller of the two, first borrow one whole unit from the top whole number and convert it into the fractional equivalent of a whole number. Add this and the fraction you already have; then proceed with the subtraction.

Examples:

$$\begin{array}{rcl} 29\frac{1}{4} & = & 28\frac{5}{4} \\ -15\frac{3}{4} & = & 15\frac{3}{4} \\ \hline & & 13\frac{2}{4} = 13\frac{1}{2} \end{array}$$

22. Decimals

22-1. In airframe repair, as in many other fields, it is often advantageous to use a form of fraction known as a decimal. Decimal fractions are tenth parts of a unit indicated by tenths, hundredths, thousandths, etc. The denominator of a decimal is the numeral 1, followed by one or more zeros. For this reason, it is possible to use an abbreviated method of writing decimal fractions. Instead of drawing a line below the numerator and writing the denominator below, the line and denominator are omitted in a decimal fraction and replaced by a decimal point.

22-2. **Reading Decimals.** The decimal point is written at the left of the number expressing the numerator. For example 0.5 is a decimal and is read point 5, or five tenths. Its value is the same as the fraction 5/10.

22-3. Read a decimal precisely as if it were a whole number, and then give it the name of the lowest decimal place. Point 1 (0.1) is read one tenth, point 01 (0.01) is read one hundredth, point 001 (0.001) is read one thousandth, etc.

22-4. An example of decimals you will be using is a number 39 twist drill, which is 0.099 inch in diameter; the decimal 0.099 is read ninety-nine thousandths. Another example is 24-gage sheet metal, which is 0.025 inch thick; the decimal 0.025 is read twenty-five thousandths.

22-5. A mixed number with decimals such as 1.25 is read one and twenty-five hundredths, or simply one point twenty-five.

22-6. **Changing Fractions to Decimals.** To change a common fraction to a decimal fraction, divide the numerator by the denominator.

Example:

$$\begin{array}{rr} 7/8 & 0.875 \\ & 8\,)\,7.000 \\ & \underline{6\,4} \\ & 60 \\ & \underline{56} \\ & 40 \\ & \underline{40} \end{array}$$

Therefore,

$$7/8 = 0.875$$

22-7. **Changing Decimals to Fractions.** To change a decimal fraction to a common fraction, omit the decimal point, write the understood denominator, and reduce to lowest terms.

Example:

$$0.875 = \frac{875}{1000} = \frac{35}{40} = \frac{7}{8}$$

22-8. **Using Decimal Equivalent Charts.** Figure 125 is a decimal equivalent chart which you can use to convert fractions to decimals and decimals to fractions without using the preceding mathematical procedures. The chart contains the decimal equivalents of all fractional values from 1/64 to 64/64. In shop work, you will save time by using the decimal equivalent charts; however, sometimes you will encounter fractions that are not on the chart and must be figured arithmetically.

CHAPTER 5

Shop Mathematics

THE SHOP mathematics discussed in this section includes adding, subtracting, multiplying, and dividing whole numbers, decimals, and fractions.

2. If you have little background in math, this will improve your ability to perform most of the mathematical problems related to airframe work. If you have a good background in these functions of mathematics, this text and review exercises will serve to refresh your memory.

3. You will frequently use shop mathematics in such jobs as developing layouts and patterns for airframe repairs, fabrications, and installations.

21. Fractions

21-1. A fraction is a number which shows the number of equal parts of a unit that have been taken, as 3/4, 7/32, or 9/16. Thus, 3/4 shows that 3 of the 4 parts of a unit are taken, 7/32 shows that 7 of the 32 parts of the unit are taken.

21-2. The *terms* of a fraction are the *denominator* and the *numerator*.

21-3. The *denominator* is the number which shows into how many equal parts the unit has been divided. The denominator is written *below* the line.

21-4. The *numerator* is the number which shows how many equal parts of the unit have been taken to make a fraction. The numerator is written *above* the line.

21-5. A *common fraction* is a fraction which has both terms expressed.

21-6. A *proper fraction* is one whose numerator is less than its denominator, as: 3/8, 5/16.

21-7. A *mixed number* is a number composed of an integer (whole number) and a fraction taken together, as: $3\frac{3}{4}$, $7\frac{1}{2}$.

21-8. A *complex fraction* is a fraction in which one or both of its terms is a fraction or mixed number, as: 3/4 over 6, 1/3 over 32, $3\frac{1}{4}$ over $7\frac{5}{8}$.

21-9. *Improper fractions* are those with a numerator larger than the denominator such as 9/8. The fraction 9/8 may be considered to be the sum of 8/8 plus 1/8. It is customary to change improper fractions to mixed numbers by dividing the numerator by the denominator. The quotient (or result) is expressed as a whole number followed by a fraction in which the remainder is the numerator, and the denominator is the same as before. For example: $9/8 = 1\frac{1}{8}$, since 8 is contained in 9 one time with a remainder of 1.

21-10. Sometimes, as in multiplication, it is desirable to convert a mixed number to an improper fraction. This can be done by reversing the above process. To accomplish this conversion, multiply the whole number by the denominator of the accompanying fraction and add the numerator; then use this number as the new numerator, and the denominator remains the same as in the mixed number. Thus, to change $2\frac{3}{4}$ to an improper fraction, multiply 2×4 and get 8; and $8 + 3 = 11$. Putting this 11 over the original denominator 4 you now have 11/4.

21-11. When both the numerator and denominator of a fraction contain a common factor, the fraction should be reduced by this factor. That is, the numerator and the denominator are divided by the common factor. For example, the fraction 6/8 can be reduced by dividing both the 6 and the 8 by 2. The answer is 3/4, which has the same value as the original 6/8. This process is called *reducing* a fraction *to* its *lowest terms.* If both the numerator and denominator of a fraction are either multiplied or divided by the same number, the value of the fraction is not changed.

21-12. **Multiplying Fractions.** Perhaps the simplest operation with fractions is multiplication such as $1/4 \times 3/4 = 3/16$ and $2 \times 3/4 = 6/4 = 1\frac{2}{4} = 1\frac{1}{2}$. When mixed numbers are to be multiplied, first change each to an improper fraction and proceed:

$$1\frac{2}{3} \times 3\frac{1}{2} = 5/3 \times 7/2 = 35/6 = 5\frac{5}{6}$$

$$1\frac{1}{4} \times 2\frac{1}{2} = 5/4 \times 5/2 = 25/8 = 3\frac{1}{8}$$

21-13. Frequently, you can simplify the multiplication of fractions by performing certain divisions of numerators and denominators before proceeding with the indicated multiplication. For instance, you can multiply 3/10 by 4/9 in the following way.

Example:

$$\overset{1}{3}/\underset{5}{10} \times \overset{2}{4}/\underset{3}{9} \quad 2/15$$

21-14. Here you divided (commonly called canceling) before performing the indicated multiplication. The numerator 3 and the denominator 9 were divided by the common factor 3. The numerator 4 and the denominator 10 were

2-3 233

53450 02 26

WORKBOOK

Fundamentals of Metalworking

SELF-TEACHING AIDS
CRE
VRE
SRG

This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

EXTENSION COURSE INSTITUTE
Air University

TABLE OF CONTENTS

Study Reference Guide

Chapter Review Exercises

Answers to Chapter Review Exercises

Volume Review Exercise

ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number	*Guide Numbers 200 through 244*
200	Introduction to Aircraft Metals; Aluminum: General; Types; Properties of Metals; Selection Factors, pages 1-4
201	Aluminum: Aluminum: Four-Digit Index System; Temper Designations; Alclad and Pureclad; Methods of Identifying Materials, pages 4-9
202	Aluminum: Heat-Treatment, pages 9-13
203	Aluminum: Requisitioning: Storage, pages 13-17
204	Aluminum: Working Characteristics; Inspection of Aluminum Repairs, pages 17-19
205	Titanium: General; Crystal Structure, pages 19-23
206	Titanium: Characteristics; Identification, pages 23-26
207	Titanium: Working Characteristics; Marking Methods, pages 26-31
208	Titanium: Heat-Treatment; Cleaning; Ordering Titanium; Inspection of Titanium Repairs, pages 31-35
209	Steels: General; Identification; Methods of Identification; Types, Characteristics, and Uses of Alloyed Steels, pages 35-38
210	Steels: Principles of Heat-Treatment; Heat-Treating Equipment; Corrosion Resistance, pages 38-43
211	Steels: Working Steels; Working Stainless Steels; Requisitioning Steel; Storage; Inspection of Steel Repairs, pages 43-48
212	Magnesium: General; Identification; Types of Magnesium; Characteristics: Alloys and Their Uses, pages 48-52
213	Magnesium: Working Characteristics; Corrosion Prevention, pages 52-54
214	Magnesium: Heat-Treating; Requisitioning Magnesium; Storage of Magnesium Sheet; Inspection of Magnesium Repairs, pages 54-58
215	Interchangeability, pages 58-62
216	Introduction to Corrosion Control of Metals; Corrosion Recognition: General; Corrosion Defined; Factors in Corrosion Control; Causes of Corrosion; Visual Inspection, pages 63-68
217	Corrosion Recognition: Types of Corrosion; Inspection Procedures, pages 68-74
218	Corrosion Prevention: General; Safety; Storage, Handling, and Use of Chemicals, pages 74-77
219	Corrosion Prevention: Aluminum, pages 77-79
220	Corrosion Prevention: Titanium, pages 79-82
221	Corrosion Prevention: Ferrous Metals Other Than Stainless Steel, pages 82-86
222	Corrosion Prevention: Stainless Steel and Nickel-Base Alloys, pages 86-89
223	Corrosion Prevention: Magnesium; Typical Aircraft Repair Protection, pages 89-92
224	Introduction to Metal Cutting; Metal Shearing Tools, pages 93-100
225	Metal Cutting Tools, pages 100-106
226	Drill Fixtures, pages 106-109
227	Twist Drills, pages 109-112
228	Punches, pages 112-114
229	Abrasive Tools, pages 114-118
230	Introduction to Hand and Machine Forming of Metals; Blueprints, pages 119-122
231	Drawings: General; Descriptive Terms; Lines and Their Uses, pages 122-125

Guide Number

232 Drawings: Scale and Size: Dimensioning. pages 125-130
233 Drawings: Types of Drawings. pages 130-136
234 Layout and Measuring Devices. pages 136-141
235 Methods of Pattern Development: General; Parallel Line Development; Radial Line Development; Triangulation. pages 141-145
236 Methods of Pattern Development: Making Layouts. pages 145-148
237 Methods of Pattern Development: Making Straight Line Bends. pages 148-152
238 Folding and Forming Equipment: General; Bar Folder; Cornice Brake; Box and Pan Brake. pages 152-155
239 Folding and Forming Equipment: Hand-Operated Slip Roll Forming Machine; Power-Operated Slip Roll Machine. pages 155-158
240 Folding and Forming Equipment: Rotary Machines; Power Flanging Machine; Stretching and Shrinking Machine; Arbor Press. pages 158-162
241 Hand Forming: General; Hammers and Mallets; Pliers; Holding Devices. pages 162-165
242 Hand Forming: V-Blocks; Hardwood Form Blocks; Shrinking Blocks; Sandbags; Forming Operations and Terms; Dollies and Stakes. pages 165-167
243 Hand Forming: Formed or Extruded Angles; Flanged Angles; Curved Flanged Parts. pages 167-170
244 Hand Forming: Bumping; Joggling; Working Magnesium. pages 170-173

CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your response against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

SECTION 1

Objective: To identify, describe, and distinguish the properties and working characteristics of aluminum and aluminum alloys.

1. Aluminum is one of the earth's most abundant metals. What portion of the earth's crust contains aluminum? What is the name of the mineral when found in ore form? (1-1)

2. Explain what is meant by nonferrous when describing metals. Name four nonferrous metals. (1-2)

3. Define "hardness" when referring to the condition of a metal as being hard. How does metal obtain this hard condition? (1-4)

4. What does the term "malleable" mean when used to describe the characteristic of a metal? (1-5)

5. Explain how the elasticity of metal is considered in the design and construction of aircraft parts. (1-7)

6. Define "fusibility" as used in describing a metal characteristic. At about what temperature does steel fuse? At about what temperature does aluminum fuse? (1-11)

7. What are the three primary factors to consider in selecting a particular metal for airframe construction and repair? (1-15)

8. Define the term "heat-treatment" as it pertains to aluminum alloys. (1-27)

9. What two general fabrication processes are used on aluminum alloys? (1-36)

10. In the four-digit index system, to what major alloying elements do 2XXX, 3XXX and 4XXX refer? (1-52)

11. Using the metal marking: *ALCOA 2024–T3 0.040 QQ–A–250/5*, identify the temper condition, specification number, and thickness of the material. (1-55; Fig. 3)

12. If a technical order repair figure specified a repair material of QQ–A–250/11 H–38, describe the type of alloy and identify the tempering process required prior to use of the metal on an aircraft. (1-55, 57; Table 2)

13. Differentiate between the various procedures for heat-treating and strain-hardening aluminum alloys. (1-57, 76)

14. You are forming a "U" channel with 2024–T3 aluminum alloy with a thickness of 0.064 inch. The bend radii is such that it cannot be safely formed in the –T3 condition. What treatments are necessary before and after forming the part? (1-97–103; Tables 3, 4)

15. You are inspecting an aluminum repair job. List some of the questions that must be answered satisfactorily before you approve the repair. (1-125)

SECTION 2

Objectives: To identify, differentiate, and describe the marking, specifications, working characteristics, and heat-treating procedures of titanium alloys.

1. What is meant by the A-B-C system of classification of titanium? (2-5)

2. Identify the military specification for the material, if during a repair the –3 technical order specified a repair material of Ti–5A1–2.5Sn, AMS 4926. (Table 8)

3. Titanium is similar in appearance to stainless steel. What two simple tests may be used to identify titanium? (2-22)

4. Using the metal marking *TIMET TYPE I COMP B GA .040 HEAT D MIL–T–9046D*, identify the manufacturer or the trade name, the type of titanium alloy, composition, heat-treatment, and specification number. (2-25)

5. What conditions will you likely encounter in shearing titanium? (2-27)

6. What special treatment is necessary for forming small radii on titanium alloys? (2-31)

7. In fabricating a titanium repair, if the material Ti–8Mn, AMS 4908A, 0.050 thickness requires a bend radius of one times its thickness, what further treatment would be necessary? Describe the necessary procedure. (Tables 10, 16)

8. Titanium is different from most metals in that hydrogen embrittlement presents a major problem. Describe the fabrication process in which this is most critical. (2-52)

SECTION 3

Objective: To identify the composition, working characteristics, markings, and heating procedures of steel and steel alloys.

1. Define the letters SAE used in the numbering system of steel identification. (3-4)

2. A piece of metal is marked *CRUCIBLE SAE 4150 MIL–S–18729*. What is the meaning of each of the markings? (3-6, 8)

3. Identify the technical order you could refer to for specific identification and testing processes for metals. (3-15)

4. Identify the carbon content of steels classed as low, medium, and high carbon steels and the SAE numbering applicable to each. (3-19–21)

5. State the major alloying elements of the material specified, and describe the forming advantages of the material if, during a repair, the –3 technical order specified repair material of 18–8 CRS. (3-24, 25)

6. Explain why oil is preferable to cold water in the quenching of steels after heat-treatment. When water is used it should be heated to what temperature? (3-40, 41)

7. What procedure produces a hard, wear-resistant surface over a strong, tough core on steel material? What are the two principal ways of obtaining this surface? (3-49)

8. What is carburizing? What is nitriding? (3-54)

9. What is the minimum chromium content of stainless steel? What does chromium do to the metal to create this stainless or corrosion-resisting quality? (3-79)

10. What do most stainless steels require to develop maximum corrosion resistance, and at what temperature are quenching stresses relieved in stainless steel? (3-81)

11. How are drill cutting angles, drill speeds, and the amount of pressure applied on stainless steel different from similar operations on other types of steel? (3-85–88)

12. During a repair requiring 4130 normalized steel sheet, 0.063 thickness, the metal requires smaller bending than a bend radius of three times its thickness. What does it need to be formed? (3-109, 110; Table 20)

SECTIONS 4 AND 5

Objective: To interpret markings, identify specifications, and be able to explain the distinguishing working characteristics and heat-treating procedures of magnesium alloy sheet.

1. Interpret and define the meaning of each of the markings on a sheet of magnesium alloy received in your shop marked: *DOW 0.032 AZ31B QQ-M-44.* (4-8; Tables 22, 23)

2. What happens when you use a one-half of one percent silver nitrate solution on magnesium? On aluminum alloy? (4-9)

3. Name the three casting processes used for casting magnesium alloy parts. (4-17)

4. If a piece of magnesium has a temper designation of -H16, how do you interpret this symbol? (4-28)

5. In what type of container do you place magnesium dust, and what are the recommended extinguishing agents for use in the event of fire? (4-49, 50)

6. What is the distinguishing characteristic in the forming of magnesium? (4-51, 52)

7. What bend radii must be incorporated in the annealed and hard-rolled sheet magnesium when formed cold? (4-56)

8. If during a repair a –3 technical order specifies a material as AN–M–29, what is the Federal specification, chemical composition of aluminum, manganese, and zinc? In which wrought form is this specification used? (Tables 22, 23)

9. A repair figure in a –3 technical order specifies a material of HK 31A, 0.062 thickness, and is required in a repair that has a sharp radius 90° bend. Starting with the annealed material, identify and explain the heat-treating requirements needed on the material prior to installation on an aircraft. (4-67, 68; Tables 24, 25)

10. List the four principal requirements that must be considered in the substitution of metals. (5-2)

11. In regard to the above substitution requirements, what are the factors governing each? (5-7, 10-12)

12. Using table 27, identify dimensions and forming angles of sheet metal stock substituitions, compared with the original for extrusion number NAS 344–43. (5-19, 20; Table 27)

13. Using table 28, compute the thickness of material clad 2014–T4 required to replace a piece of clad 2024–T36, 0.040 thickness for a repair. (5-23, Table 28)

CHAPTER 2

SECTION 6

Objectives: To explain, describe, and define the terms associated with the *identification* and *causes* of corrosion.

1. List and explain five factors that affect the rate of corrosion of metal. (6-7–11)

2. Give four causes for electrochemical corrosion. (6-14, 15)

3. When zinc and copper material are immersed in an electrolyte and contacted electrically, a current will flow. Which of the metals will corrode and why is the other metal protected? (6-26; Table 29)

4. Identify this type of corrosion: A white powdery deposit similar to dust is found on thin sections of magnesium or aluminum alloys. Why is this serious? (6-40, 41)

5. Where is intergranular exfoliation most often found? In what way does it usually manifest itself? (6-47)

6. Define the meaning of "a galvanic couple." and explain how tin-covered metal tends to contradict the rule of the galvanic series. (6-49, 50)

7. Describe concentration-cell corrosion. (6-58, 59)

8. Briefly explain the procedure for inspecting the four basic areas of an airframe for corrosion. What is done with the noted inspection discrepancies? (6-65–69)

SECTION 7

Objective: To show an understanding of precautions and procedures for removing or preventing corrosion on metallic parts.

1. Describe how the human skin is normally affected when a dust created by dry acid is in contact with the skin and is activated by perspiration. (7-4)

2. What is the difference between a gas and a vapor? (7-5)

3. If you were to open a container of paint remover taken from a hot storage area, what reaction would likely occur? (7-12)

4. Explain the action you should take when a person you are working with has been asphyxiated. (7-16)

5. When corrosion is present on aluminum or aluminum alloy and the part may be easily removed for treatment, what procedures would be used to clean grease and paint from the surface of the part? (7-23)

6. What will likely happen if, prior to paint stripping, bonded aluminum surfaces in oxygen areas are not masked off? (7-27)

7. When you strip paint on aluminum surfaces in oxygen areas, what chemicals do you use? Why must they be kept clear of elastomers? (7-29)

8. Where is metal conditioner and brightener, Specification MIL-C-25378, used and where is it not to be used? (7-36, 37)

9. Explain why oxides should be removed by using acid-pickling solution on titanium alloy only when other methods have failed. (7-49)

10. Explain how, after the acid pickling treatment is complete, titanium is rinsed and dried. (7-52)

11. Of the two methods of corrosion removal, which is preferred on ferrous metals? Explain why. (7-61)

12. Prior to the use of acid chemicals, what must first be done with the heavy rust on ferrous metals? (7-70)

13. Explain why common steel wool and common steel wire brushes are not to be used on stainless steel material. (7-88)

14. On stainless steel, how is blending done and for what purpose? (7-88)

15. What type of chemical corrosion removal material is used in areas of oxygen transfer and storage, for the removal of corrosion on stainless steel material? (7-89)

16. Why do we not remove corrosion from heat-treatable straight chromium stainless steel alloy by the use of pickling solution? (7-89)

17. What is the maximum temperature of acid-pickling solution for use on stainless steel? Explain the results if this temperature is exceeded. (7-91)

18. State the advantages of the chromic acid brush-on pretreatment of magnesium over other brush-on methods of pretreatment. (7-103)

19. Explain the results of using wash-primer MIL–C–8514 on bare magnesium without pretreatment of chromic acid brush-on solution. (7-104)

CHAPTER 3

SECTION 8

Objective: To recognize metal cutting machines used to shear material and to show a knowledge of their applications and limitations.

244

1. With what types of gages are utility lever shears equipped, and what are the functions of these gages? (8-2)

2. What is the distance from the centering pin to the cutting blade on circle shears (fig. 21) if a round disc 10 inches in diameter is to be cut? (8-12)

3. The squaring shears shown in figure 22 can be used to cut a straight line on a piece of sheet stock. If the metal was placed in the shear with the scribed line in position before the treadle was operated, but the metal slipped and the cut missed the line, what mistake was made? (8-16, 17; Fig. 22)

4. What mistake was made in the cutting process if a piece of sheet stock was cut ¼ inch too short on one side? The production gage of the manually operated squaring shears was used properly and the holddown handles were locked. (8-19)

5. If you are using a power-operated squaring shear, how would you trim ¾ inch from the 10-inch side of a 10- by 16-inch piece of sheet stock? (8-22)

6. What is the main advantage that stationary and portable unishears have over hand snips? (8-26)

7. What are the safety measures to follow when you use unishears? (8-30)

SECTION 9

Objectives: To recognize common metal cutting tools, to show a knowledge of their proper use, and knowledge of procedures necessary for proper and safe application.

1. If your coworker is cutting a 5-inch hole in an aluminum panel and asks you for a pair of left-hand snips, what kind of snips would you hand him? (9-2)

2. During inspection of a pair of hand snips, you discover a half-round notch indented in each of the blades. What misuse of the snips probably caused the damage? (9-5)

3. What mistake was made in the sharpening process if the cutting edge of a chisel becomes blunt when splitting rusted bolts or nuts? How should this mistake be corrected? (9-10)

256

4. Why is it important to keep chisel heads dressed? (9-11)

5. In figure 31, a hack saw blade with 32 teeth per inch is recommended for cutting thin wall tubing. What *type* of hack saw blade should be used for cutting this tubing? (9-12; Fig. 31)

6. A piece of thin wall tubing is being sawed with a hack saw that has a 32-teeth-per-inch blade. Although you are using 40 to 50 strokes per minute, the blade doesn't seem to be cutting as it should. What is wrong? (9-13)

7. Cutting oil ceases to flow from the lubricating tube of a power hack saw, although the pump is operating and the fluid level is adequate. What is the likely cause? (9-17)

8. When you cut a 3-inch-diameter hole in a metal laminated panel, which saw is best suited? (9-36)

9. A job requires a $3\frac{3}{16}$-inch-diameter hole which is perfectly round, has clean sides, and has no taper. A hole saw of this size is not available. What is the most suitable cutting device for you to use? (9-37)

SECTION 10

Objective: To show a knowledge of the proper usage, care, and correct operation of drill fixtures and their limitations.

1. Why is it best to use a hand drill for drilling 0.063-inch aluminum sheet stock? (10-2)

2. You are inspecting twist drills for wear and breakage and discover grooves and burrs on the shank of a twist drill. What is the cause? (10-4)

3. While drilling holes in 0.050-inch sheet stock with a $\frac{3}{16}$-inch twist drill, you notice that the holes are larger than $\frac{3}{16}$ inch. What is the probable cause? (10-5)

4. Which drilling or punching equipment creates the most dangerous eye hazard? (10-10)

5. Which drilling fixture is best suited to drill a $\frac{9}{16}$-inch hole in a piece of flat bar stock 1¼ inch by 1 inch by 3 inches that will be tapped 1½ inches from the end? (10-10)

6. In figure 39, is the drill press set up to operate at minimum or maximum spindle speed? (10-11; Fig. 39)

7. After a speed change has been made, what adjustment should you check before using a drill press? (10-11)

8. What is the trouble if, during a drilling operation, the drill press spindle stops turning but the motor continues to run? (10-13)

9. What is the likely cause if the working table is hard to adjust on the column of a drill press? (10-13)

SECTION 11

Objective: To be able to differentiate between types and sizes of twist drills and to show a knowledge of proper application and limitations of twist drills.

1. In what three ways can a twist drill become overheated if used to drill a metal beam 1/2 inch thick? (11-1)

2. What are the two size designations of twist drills that can be used for drilling a hole 0.250 inch in diameter? (11-2; Fig. 40)

3. Examination of a hole reveals several long, circular scratches and the hole is to be 1/8 inch to the left of the intended mark. What mistake was made when preparing to drill the hole? (11-5)

SECTION 12

Objectives: To be able to identify punching tools as to their function, limitations, and correct application. To understand safety procedures and correct maintenance of punching tools.

1. Which hand punch is used when you transfer paper patterns to sheet stock? (12-4)

2. When using a Whitney punch such as illustrated in figure 46, what is the maximum distance that a hole can be punched from the edge of a sheet, and what factor governs this distance? (12-11; Fig. 46)

3. What is the advantage of center punching a piece of metal prior to punching a hole with a rotary punch? (12-17)

4. During inspection of a rotary punch, you discover that one of the punches has a chipped edge. What is the probable cause? (12-18)

5. What are the important steps for preventive maintenance on the rotary punch? (12-19)

SECTION 13

Objectives: To understand the purpose of abrasive tools, and to recognize the hazards of improper use and care of such tools.

1. What shape and type of file should you use to remove the metal burrs from the edge of a 3-inch diameter hole that has been made with a hole saw? (13-2)

2. What should be done if a file becomes clogged with filings? (13-3)

3. What can be used, other than a twist drill, to enlarge a hole in sheet metal stock that is $\frac{1}{16}$ inch too small in diameter? (13-8)

4. What is the minimum safe clearance between the work rest and abrasive wheel when grinding metal $\frac{3}{16}$ inch thick? (13-20)

CHAPTER 4

SECTION 14

Objectives: To demonstrate a knowledge of blueprints and microfilms and the ability to interpret blueprint contents.

1. On a blueprint the scale is shown as 4 inches = $\frac{1}{2}$ inch. What is the scale of the drawing compared with the original object? (14-12)

2. What is meant by tolerance? (14-24)

3. What is the primary advantage of microfilm over drawings? (14-31)

SECTION 15

Objectives: To show a knowledge of the purposes, symbols, and characteristics of different types of drawings. To interpret and analyze facts and principles pertaining to the different techniques of illustrating objects.

1. How do we indicate the size and shape of a working drawing? (15-9)

2. In drawings, what is the difference in how a visible outline and an invisible outline are shown? (15-10, 11)

3. How is a broken material line identified and what does it signify? (15-16)

4. When a cutting plane line and a center line appear at the same place, which one remains to help identify the drawing? (15-12, 17)

5. How is an arc dimensioned? (15-32)

6. What is the preferred location for dimensions of a circle? (15-38)

7. A given dimension is 2.375. How would you interpret this figure? (15-42)

8. What is an orthographic drawing? (15-53, 54)

9. What type drawing is used to show inclined surfaces completely? (15-58)

10. If a triangular gusset made of 0.051-inch material was shown in a drawing, how many views would need to be shown? Why? (15-71–73)

11. In the case of an invisible line being directly behind a visible line, which one will be represented on a drawing? (15-83)

12. What are working drawings and for what purpose are they used? (15-88, 89)

13. What kind of drawing is made to show the complicated inside of objects? (15-94)

14. How much of an object is viewed when a drawing shows a full section? (15-95, 97)

SECTION 16

Objective: To exhibit a knowledge of drawing and measurement tools, their utilization, and limitations.

1. What two purposes does a rule serve? (16-6)

2. What drawing instrument would you use for drawing vertical lines? (16-9)

3. What kind of measurement is taken with an outside caliper? (16-16)

4. When extreme accuracy is demanded in measuring an aircraft part, what tool is used and to what accuracy can it measure? (16-19)

5. If a micrometer is to be read to one ten-thousandths of an inch, which parts of the micrometer must be used? (16-21–27)

6. What does the protractor head of a combination set read? (16-37)

SECTION 17

Objective: To interpret and analyze facts and principles pertaining to the different methods of pattern development.

1. What are the three methods of pattern development? (17-3)

2. What is a stretchout? (17-6)

3. How is the length of a stretchout line obtained? (17-14)

4. In the layout of elevation view, when is it not necessary to show true lengths? (17-19)

5. Is triangulation more or less accurate than parallel or radial line development? (17-22)

6. In radial line development and triangulation, from what view is the slant height of the object obtained? (17-15, 23)

7. Early in sheet metal layout you should make your layout on paper. Why? (17-24)

8. Why is it important, in bending aluminum alloy, to have relief holes? (17-35)

9. Why are flanges usually formed around lightening holes? (17-38)

10. What is the purpose of lightening holes? (17-38)

11. What does the term "minimum bend radius" mean? (17-45)

12. What is bend allowance? (17-49)

13. Where are bend tangent lines located? (17-64)

14. What is the formula used to find setback? What do the symbols in the formula mean? (17-65–68)

15. What is the purpose of the sight line when you bend metal with a cornice brake? (17-69)

SECTION 18

Objectives: To exhibit a knowledge of the working characteristics of curve forming machines, slip roll former, and rotary machines. To show an understanding of the characteristics, limitations, and adjusting procedures of folding machines.

1. What is out of adjustment if a bar folder is hard to operate when bending sheet stock that is within the capacity of the machine? (18-4)

2. What adjustment is incorrectly made on a bar folder if the desired bend is 110° but the piece of metal being folded is 110° on one end and 115° on the other? (18-4)

3. What three adjustments should be made on the bar folder if you are making duplicate 80° beads in 0.051 material ¾ inch from one edge? The bar folder was last used to bend 0.025-inch material at 60° bends. (18-4, 6, 8)

4. How can duplicate bends of 50° be made with a bar folder? (18-8)

5. What safety feature of a bar folder allows you to keep one hand clear of the folding blade when making a bend? (18-9)

6. How may the process of duplicating angles on a cornice brake be speeded up? (18-11; Fig. 102)

7. What are two adjustments that should be made on a cornice brake if you are going to bend 0.063-inch material and the cornice

brake was last used to bend 0.040-inch material? (18-13)

8. Why must a cornice brake be level on the floor when you adjust a creeping top leaf? (18-13)

9. What adjustment was made incorrectly on a cornice brake if, while you are bending a piece of metal to a right angle, one end becomes 90° and the other 100°? (18-16)

10. What folding machine is best suited to form a ¾-inch standing seam on four sides of a sheet of metal? (18-19)

11. What folding machine should you use to complete the forming of a container that will be 10 inches wide, 24 inches long, and 4 inches deep? The long sides have been already formed on the cornice brake. (18-19)

12. What shapes may be formed with the slip roll forming machine? (18-22)

13. To decrease the radius of forming, which roll of the slip roll forming machine is moved and in what direction? (18-22)

14. What mistake was made in using a hand-operated slip roll forming machine if a cylinder is overformed on one end and underformed on the other? (18-24)

15. What mistake was made when using the power-operated slip roll forming machine to form ⅛-inch steel into a cylinder if all but the last 4 inches have the correct radius? The front and rear lower rolls are adjusted properly. (18-29)

16. What should be done to the rollers on a slip roll forming machine if it has been used to form black iron that has a coating of rust inhibitor which came off on the rolls? (18-30)

17. What is unusual about loosening the nuts that hold the rollers on rotary machines? (18-34)

18. The vertical distance between the rollers of a rotary burring machine are set correctly; however, the metal is cut as it rotates between the rollers. What is the likely cause? (18-36)

19. What mistake was made when turning metal on a rotary turning machine if the metal slips out of the rollers during the first revolution? The metal allowance was sufficient. (18-39)

20. If during the process of edging an elbow on the elbow edging machine the gage was found to be impractical due to size or shape, how would the material be marked and how much material would be allowed for the lock seam? (18-41)

21. What is the purpose of crimping metal with a rotary crimping machine? What about the seam on the material? (18-48, 49)

22. What mistake was made on the rotary beading machine if the beads do not meet after the first revolution? (18-52)

23. How is the power flanging machine adjusted to hold the proper thickness of material? (18-54)

24. In what position should you have the foot pedal of the stretching and shrinking machine while you adjust the machine for material thickness? (18-59)

25. What is the primary purpose of the arbor press as used in airframe repair? How is that purpose accomplished? (18-62)

SECTION 19

Objectives: To understand the procedures necessary to hand form metal into aircraft parts and to exhibit a knowledge of the tools and equipment necessary to fabricate those parts.

1. What is the difference between hammers and mallets and how are they classified? (19-3–10)

2. What is the method for planishing? (19-7)

3. How are roundnose pliers used to crimp metal without springing the jaws of the pliers? What should be used for that purpose on heavy work? (19-13, 16)

4. Name two methods of shrinking metal during hand forming. (19-24, 27)

5. What kind of parts are most suitable for forming on V-blocks? (19-24)

6. What does the term "bumping" mean, as used in hand forming? (19-32)

7. What are the two common methods of shrinking metal by hand forming? (19-36)

8. If you are required to make an extremely sharp bend in a flanged piece of metal, what method would you most likely use? (19-38)

9. What is the primary purpose of bench stakes? Which is the most appropriate stake for forming sharp, straight bends? (19-39, 48)

10. How can you recognize work-hardening? (19-58)

11. What is the technique of "crimping?" (19-63)

12. Of the various types of nose ribs discussed in this chapter, which is the most easily hand-formed? (19-69, Fig. 121)

13. What would you use as a pattern to form a piece of metal into a desired shape if the machines in the shop cannot be used? (19-80)

14. List one advantage and one disadvantage a sandbag will have compared with a wood or metal form block when you are forming a dish-shaped object from annealed aluminum. (19-81, 88)

15. What is a joggle? (19-92)

SECTION 20

Objective: To exhibit a knowledge of the advantages and disadvantages of forming magnesium and magnesium alloys.

1. When you cold-work magnesium alloys, the radius of bend is not the same as when you work aluminum or steel alloys. What must the radius of bend be when you bend soft and hard magnesium alloys cold? (20-3)

2. If proper precautions are taken, what is the quickest way to soften, by heating, small pieces of magnesium alloy for bending? (20-8)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

Section 1

1. One-twelfth. Alumina (aluminum oxide). (1-1)
2. Metals that have elements other than iron as the principal constituent or base are classified as nonferrous. Copper, magnesium, titanium, and aluminum are nonferrous metals. (1-2)
3. Hardness is the ability of a metal to resist abrasion, penetration, cutting action, or permanent distortion. Hardness of a metal is obtained by cold-working or heat-treating. (1-4)
4. A metal that can be hammered rolled, or pressed without cracking or breaking is considered malleable. (1-5)
5. Using the known elastic limits of each individual metal, parts are designed so that their elastic limit will never be exceeded. (1-7)
6. The ability of a metal to become liquid by heat application. Steel fuses at approximately 2500° Fahrenheit. Aluminum at approximately 1100° Fahrenheit. (1-11)
7. Strength, weight, reliability. (1-15)
8. Heat-treatment of aluminum includes hardening and toughening, called heat-treatment; and softening, called annealing. (1-27)
9. Casting alloys and wrought alloys. (1-36)
10. Copper, manganese, and silicon. (1-52)
11. The number 2024–T3 indicates the alloy temper; QQ–A–250/5 is the Federal specification; and 0.040 is the thickness. (1-55; Fig. 3)
12. 6061 aluminum alloy, strain-hardened and stabilized to the full hard condition. (1-55, 57, Table 2)
13. Strain-hardening causes aluminum to become stronger and harder as it is rolled, formed, or otherwise cold-worked. Heat-treatment further improves the desired strength and hardness of aluminum alloy by heating, quenching, and ageing. (1-57, 76)
14. Prior to forming, anneal by heating the metal to 750° to 800° Fahrenheit for 30 to 40 minutes and cool in air. After forming, heat-treat from 30 to 40 minutes at a temperature of 910° to 930° Fahrenheit and immediately quench in cold water. (1-97–103; Tables 3, 4)
15. (1) Are replacement and reinforcement parts similar to the original in composition and strength?
    (2) Has the material been protected by corrosion preventive?
    (3) Has cracking been avoided?
    (4) Is the surface free of scoring and scratches?
    (1-125)

Section 2

1. The A-B-C is a simple system of describing all alloys of titanium. A denotes alpha alloys; B, beta alloys; and C, the combined forms of alpha and beta alloys. (2-5)
2. MIL–T–9047B–2. (Table 8)
3. The spark test: When applied to an abrasive grinder, titanium produces brilliant white sparks. In the second test, you moisten the edge of a piece of titanium and draw a line on a piece of glass with the edge of the titanium, leaving a mark similar to a pencil line on the glass. (2-22)
4. Trade Name: Timet
   Type: 1
   Composition: B
   Heat-treatment: D
   Specification number: MIL–T–9046D
   (2-25)
5. Knife life will be short, maintenance cost high, and you will be required to smooth the edges by hand filing. (2-27)
6. In forming, the titanium alloy needs to be heated to about 500° Fahrenheit for sharp radius bends. (2-31)
7. Annealing, because the recommended minimum cold bend radius for Ti–8Mn is three times the thickness of the material. Solution heat-treat the material at 1250° to 1300° Fahrenheit for 1 hour, slow cool to 1000° to 1050° Fahrenheit maximum in a furnace at a maximum rate of 300° Fahrenheit per hour. (Tables 10, 16)
8. In the process of acid pickling or scale removal baths. During heat-treatment at elevated temperatures, hydrogen is readily absorbed into titanium, causing embrittlement. (2-52)

Section 3

1. Society of Automotive Engineers. (3-4)
2. Crucible: Trade name.
   SAE 4150: Society of Automotive Engineers numbering system for molybdenum steel containing 1 percent molybdenum and 0.50 percent carbon.
   MIL–S–18729: Military specification which directs amount of alloying elements and the way the metal will be processed prior to acceptance for military usage. (3-6, 8)

3. Technical Order 1–1A–9, *Aerospace Metals-General Data and Usage Factors.* (3-15)
4. Low carbon steel 0.10 to 0.30 percent carbon, SAE 1010 to SAE 1030.
   Medium carbon steel 0.31 to 0.50 percent carbon, SAE 1031 to SAE 1050.
   High carbon steel 0.51 to 1.05 percent carbon, SAE 1051 to SAE 1105.
   (3-19–21)
5. 18 percent chromium and 8 percent nickel. Strength may be increased by cold-working and the metal may be rolled, drawn, bent, or formed to almost any shape. (3-24, 25)
6. Oil is much slower in quenching action and reduces the tendency of the metal to warp and crack. Cold water will cause the metal to crack if under 65° Fahrenheit because of the rapid change in the temperature variance. Over 65° Fahrenheit the water will prevent the necessary intermolecular locking required for hardness. (3-40, 41)
7. Case Hardening. The two methods are carburizing and nitriding. (3-49)
8. Carburizing means to heat steel while it is in contact with carbonic gases. Nitriding signifies heating steel while it is in contact with nitrogenous material such as ammonia gas. (3-54)
9. 12 percent chromium. In excess of 12 percent, chromium tends to develop a protective film formation on the surface of the metal. (3-79)
10. Suitable heat-treatment is required to develop maximum corrosion resistance. Quenching stresses may be relieved by tempering stainless steel at 700° Fahrenheit. (3-81)
11. Drills must have a different cutting angle of 135° to 140° included angle. Metal will harden if the speed and pressure are not closely controlled. Speeds must be reduced 25 to 50 percent compared to other steels. (3-85–88)
12. Hot-forming is required by heating the metal at a temperature of 800° to 900° Fahrenheit. (3-109, 110; Table 20)

Sections 4 and 5

1. DOW: Manufacturer's trade name.
   0.032: Thickness of the sheet in inches.
   AZ31B: ASTM composition specification.
   QQ-M–44: Federal Specification number. (4-8; Tables 22, 23)
2. The magnesium surface will turn black, but the surface of an aluminum alloy sheet will not react. (4-9)
3. Sand, semipermanent mold, and permanent mold castings. (4-17)
4. -H1 indicates strain-hardened, and 6 indicates the degree of strain-hardness (in this case, ¾ hard). (4-28)
5. Covered iron containers separated from regular floor sweepings. G-1 powder, cast iron chips, clean dry sand, graphite powder, talc, or pitch (4-49, 50)
6. Most forming operations on sheet magnesium must be done while the stock is hot. (4-51,52)
7. For annealed material, the radius must be at least 7 times the thickness of the sheet; and for hard-rolled material, at least 12 times the thickness of the sheet. (4-56)
8. Federal Specification: QQ–M–44.
   Aluminum: 3.0 percent
   Manganese: 0.20 percent
   Zinc: 1.0 percent
   Form used: Sheet stock.
   (Tables 22, 23)
9. First, the metal must be solution heat-treated at 1045° to 1055° Fahrenheit for 2 hours, then to attain the –T6 condition it must be artificially aged by heating for 16 hours at 400° Fahrenheit. (4-67, 68; Tables 24, 25)
10. Strength, contour, weight, and corrosion resistance. (5-2)
11. Substitute material must never be thinner than the original and must include strength at least equal to the original in tension, compression, shear, and bearing. Drag must not be created in the fabrication of a repair. The weight must be kept as close to the original as possible.
    Corrosion resistance is minimized by using similar metals. (5-7, 10–12)
12. Original: Base "A" = 1.750 inches wide. Leg "B" = 1.125 inches high. T_1 Base thickness = 0.078 inch wide. T_2 Leg thickness = 0.078 inch wide. Radius of bends "R" = 0.125 inch.
    Substitute: Base double "A" = 1.750 inches wide. Angle B including leg length and base thickness = 1.125 inches high. Thickness of T_1 2 each, 0.063 inch. Doubler thickness, T_2 0.063 inch. Radius of bend on angles "R," 0.13 inch. (5-19, 20; Table 27)
13. 0.058 thickness. 0.040 × 1.44 = 0.0577, or 0.058 thickness. (4-23; Table 28)

CHAPTER 2

Section 6

1. *a.* Section size: Because of the possibility of variations in composition, thick sections are more subject to corrosion than thin sections.
   b. Material selection: Normally, lighter material is more subject to corrosion than

heavier material, magnesium and aluminum corrode more readily than titanium or stainless steel.

c. Environment: Tropical temperatures, marine environments, and damp moisture areas tend to accelerate corrosion over desert or arctic conditions due to electrolyte being continuously present.

d. Heat-treatment: Improper heat-treatment will permit intergranular corrosion if the metal constituents are not properly interlocked by heat-treatment.

e. Preventive maintenance: Preventing corrosion from getting started by elimination of the electrolyte, thus keeping the metal free of contamination. (6-7–11)

2. An anode, a cathode, a continuous liquid path, and a conductor to carry the flow of electrons. (6-14, 15)
3. The zinc will corrode because it is more active (anodic); copper will be protected because it is less active (cathodic). (6-26; Table 29)
4. Pitting Corrosion: Under the dust, pits or small holes are evident. In thin sections of aluminum or magnesium alloy, pitting results in unserviceable metal due to perforation at the pit sites. (6-40, 41)
5. Thin extruded sections: The force of the expanding corrosion products occuring at the grain boundaries just below the surface shows itself by lifting the surface grains of the metal. (6-47)
6. Accelerated or galvanic corrosion will usually occur on the higher of two metals in the galvanic series that are coupled together. Tin covering of metal polarizes and acts as an insulator to the galvanic action. (6-49, 50)
7. The nonuniformity of the electrolyte creates concentration-cell corrosion. This is because the differences of the potential on the surface of the same metal (created by the concentration of metal-ions) is greater at one point on the metal than at another point. (6-58, 59)
8. Wings are inspected from tip to fuselage (the leading edge portion), fuselage to outboard (the trailing edge portion, including brackets, attaching points, and other natural moisture well areas). Fuselage is inspected from nose to tail on the right-hand side and from tail to nose on the left side (including wheel wells, spotwells, piano hinges, etc.) The empennage is inspected in the same manner as the wings. The fuselage interior is inspected systematically. Close attention is given rest and relief areas, moisture tendency wells, drain hole areas, etc. The corrosion discrepancies noted during inspection are documented on AFTO Form 781A. (6-65–69)

Section 7

1. When activated by perspiration, dry acid dust will usually cause skin irritation and/or ulceration on the human skin. (7-4)
2. A vapor is a gas given off from a substance which normally exists as a liquid and sometimes as a solid. A gas is a substance which exists as a gas in its natural form. (7-5)
3. Heat applied on a can of paint remover causes the paint remover within the can to expand. When opened, the paint remover is likely to be forced out violently, causing injury to the user. (7-12)
4. Provide fresh air and if necessary apply artificial respiration to the individual. Obtain medical assistance as soon as possible. (7-16)
5. Immersion cleaning and paint removal is accomplished with Military Specification MIL–R–7751, Paint and Varnish Remover, 3 to 5 ounces per gallon of water. Application temperature of this compound solution is between 190° and 212° Fahrenheit. (7-23)
6. Failure to seal and mask off bonded areas may cause separation or failure of the adhesives of the bonding upon application of the paint remover. (7-27)
7. In the areas of oxygen storage or transfer, dichloromethane, MIL–D–6998, ethyl acetate, or lacquer thinner is used. In areas of direct contact with oxygen, use only dichloromethane. These compounds in contact with elastomers will cause deterioration of the elastomer. (7-29)
8. MIL–C–25378 metal conditioner and brightener is used only on aluminum alloys. It is never used or rinsed over magnesium or plated steel parts, and must be kept clear of faying surfaces. (7-36, 37)
9. Because of titanium's susceptibility to hydrogen embrittlement in acid solutions. (7-49)
10. The metal must be thoroughly rinsed in cold running water. After rinsing is complete, air-dry or dry in an air furnace at 180° to 240° Fahrenheit. (7-52)
11. Mechanical removal is recommended on flat surfaces because of the thoroughness of the removal action. (7-61)
12. You must first wire brush or chip heavy rust from ferrous metals prior to chemical treatment for corrosion removal. This will facilitate chemical action during removal. (7-70)
13. When material other than stainless steel wool

or stainless steel brushes is used on stainless steel material, galvanic corrosion may be induced by the dissimilar metals imbedded in the material during the cleaning action. (7-88)

14. In blending, corrosion is removed by making a saucer-shaped depression, which eliminates the focal point of the stress concentration. (7-88)
15. For heavy corrosion, oxygen compatible material, use trichloroethylene, Specification MIL-T-27602, first; and to remove corrosion deposits remaining after this treatment, use Pasa-Jell Nr. 101, stainless steel type. Pasa-Jell Nr. 101 may be used by itself as the original treatment on light or medium corrosion deposits. (7-89)
16. Because of its susceptibility to cracking when placed in acid pickling solutions. (7-89)
17. When pickling solution is used for corrosion removal, the pickling temperature must be kept below 140° Fahrenheit maximum. Temperatures above this will multiply evaporation of the hydrofluoric acid in the pickling solution. (7-91)
18. The chromic acid brush-on treatment, compared with other treatments on installed magnesium parts, is less expensive, less critical in application and usage, less harmful to the metal when trapped in faying surfaces, and less toxic to the user. (7-103)
19. If the chromic acid pretreatment coating is not applied prior to wash primer MIL-C-8514, the wash primer will create, instead of eliminate, future corrosion. (7-104)

CHAPTER 3

Section 8

1. Angle, miter, and depth gages. They assist in cutting metal duplicates to the correct sizes and shapes without repeated layout marking and machine adjustment. (8-2)
2. The distance should be 5 inches, ½ the diameter of the disc. (8-12)
3. The metal slipped because the holddown handles were not activated to lock the metal sheet in the cutting position. (8-16, 17; Fig. 22)
4. Since the machine was properly set, the mistake must have been caused by not placing the edge of the sheet flush against the fence. (8-19)
5. ¼ inch can be cut from the width of the sheet by placing the 10-inch side against the table guide, with the end of the sheet even with the 9¼-inch calibration, and by depressing the treadle to start the cutting cycle. (8-22)
6. Speed is the main advantage. (8-26)
7. Keep hands and fingers clear of the cutting blades, avoid burrs, and check the three-prong connector before use. (8-30)

Section 9

1. Left-hand aviation snips. (9-2)
2. The damage to the blades was probably caused by someone cutting wire or rod with the snips. (9-5)
3. Too much pressure was used and the chisel became overheated, which caused the cutting edge to become soft. The soft cutting edge should be resharpened, hardened, and tempered. (9-10)
4. If chisel heads are not kept dressed, they may break off and injure you or others. (9-11)
5. A flexible type blade is recommended for cutting thin wall tubing and thin sheet stock. (9-12; Fig. 31)
6. The blade is probably installed backwards, with the angle of the teeth toward the handle. (9-13)
7. The fluid strainer is probably clogged and should be cleaned. (9-17)
8. The hole saw is best suited to cut a 3-inch-diameter hole in metal laminated panels, since these are normally composed of several light gage metal sheets. (9-36)
9. A circle cutter (fly cutter) with an adjustable arm. (9-37)

Section 10

1. Because the holes can be drilled in less time than it would take to set up a power unit. (10-2)
2. The geared chuck of the drill was not tightened enough to prevent the twist drill from slipping in the chuck, which caused grooves and burrs to form on the shank of the twist drill. (10-4)
3. The twist drill is probably bent, which caused the hole to be larger than 3/16 inch. (10-5)
4. The drill press would create the greatest eye hazard because usually small pieces of metal are drilled. These pieces should be secured to the work table. However, if the clamp should work loose and allow the piece to spin, it is possible for flying pieces of metal to hit your safety glasses or face shield. (10-10)
5. A drill press should be used to drill the hole, since the material can be clamped to the work table to insure correct location and alignment of the hole. Also, as a safety practice, small pieces of metal should always be

securely clamped during drilling operations. (10-10)

6. The drill press is set up for maximum spindle speed because the belt runs from the largest pulley on the motor to the smallest on the spindle. (10-11; Fig. 39)
7. The belt adjustment should be checked. (10-11)
8. The V-belt is loose and should be adjusted or it is broken and must be replaced. (10-13)
9. The column is probably dirty or corroded, which will cause the working table clamp to bind. (10-13)

Section 11

1. Excessive overheating of twist drills may be caused by dullness, incorrect pressure, and/or failure to use a cutting oil. (11-1)
2. Size E or size ¼-inch twist drills can be used for drilling a hole which is 0.250 inch in diameter. (11-2; Fig. 40)
3. The hole was not center punched, which allowed the twist drill to "walk" on the metal and miss the intended mark. (11-5)

Section 12

1. The prick punch is used to transfer paper patterns to sheet metal stock. (12-4)
2. The Whitney punch can punch holes that are centered as much as 1½ inches from the edge of the sheet stock; this distance is governed by the depth of the yoke. (12-11; Fig. 46)
3. Each rotary punch is made with a point which can be placed in the depression made by a center punch to assure accurate location of the hole. (12-17)
4. The lockscrews holding the die in alignment have probably worked loose, allowing the die to move out of alignment with the punch. When the punch is operated in this condition, the edge probably chipped as it missed the center of the hole in the die. (12-18)
5. It must be kept clean, must be adequately lubricated, and must be kept in proper adjustment. (12-19)

Section 13

1. You should use a round or half-round single cut file to remove the burrs. (13-2)
2. The clogged filings should be removed with a file card and brush. (13-3)
3. A rotary file can be used to enlarge the hole. (13-8)
4. The minimum clearance is ⅛ inch. The thickness of the metal being ground has no effect on the work rest distance adjustment. (13-20)

CHAPTER 4

Section 14

1. The drawing is 8 times the size of the original object. (14-12)
2. When a dimension shows on allowable variation, the sum of the plus variation figure and the minus variation figure is called tolerance. (14-24)
3. Microfilm requires very little storage space. (14-31)

Section 15

1. Shape is given a drawing by lines, and its size is indicated by dimensions. (15-9)
2. Visible outlines are represented by bold, solid lines, and invisible outlines are distinguished by a series of short dashes of medium weight. (15-10, 11)
3. The broken material line is identified by irregular solid lines of the same weight as the visible outline lines. The part on either end of the broken material line is construed to be the same between the broken material lines as shown by dimensions. (15-16)
4. When a center line and a cutting plane line overlap, the cutting plane line remains. (15-12, 17)
5. An arc dimension is always given in terms of its radius. (15-32)
6. The preferred location is outside the circle by the use of extension lines. (15-38)
7. Such a dimension (2.375) is called a decimal dimension. It indicates the allowable variance from an exact measurement and is called tolerance. (15-42)
8. An orthographic drawing shows top, front, and end views. (15-53, 54)
9. Inclined surfaces are best shown in orthographic projection by an auxiliary projection or view. (15-58)
10. One view. If more than one view was shown, the thickness would only be represented by a single line, thus confusing the illustration. (15-71–73)
11. The two features are shown as a solid line representing the visible line. (15-83)
12. A working drawing is a drawing of an object, either in part or as a whole, that shows each part in true relation to the entire object. The drawing should also indicate true and accurate dimensions. Working drawings can be used to build, manufacture, assemble, locate, and determine sizes. (15-88, 89)

13. To avoid confusion, on a drawing having a complicated interior, the object is cut into (supposedly), and then drawn. This type of drawing is known as a sectional drawing or view. (15-94)
14. When a drawing shows a full section, the draftsman views the back half or he views the part left when the cutting plane passes through the center of the object. (15-95, 97)

Section 16

1. It shows measurement and can be used as a straightedge. (16-6)
2. Triangles are used for making vertical lines during drawing or drafting. (16-9)
3. The outside caliper is used to measure round or cylindrical objects. (16-16)
4. The micrometer. The micrometer can be used to measure accurately to one ten-thousandths of an inch (0.0001). (16-19)
5. In reading a micrometer to 0.0001 inch, the barrel, thimble, and vernier scale must be used. (16-21–27)
6. The protractor head is used to measure degrees other than 45°. (16-37)

Section 17

1. Parallel line development, radial line development, and triangulation. (17-3)
2. The stretchout is the pattern of the part before it is formed. (17-6)
3. The stretchout length is the distance around the bottom of the object. (17-14)
4. When the object is a regular frustum or cone. (17-19)
5. Triangulation is and should be equally as accurate. (17-22)
6. The slant height of an object is obtained from the elevation view. (17-15, 23)
7. The practice of layout on paper provides an economical and easy way to see an object before it is actually made of metal. This practice is economical in that, if errors exist in the paper layout, they can be corrected in terms of time and material saved. (17-24)
8. To prevent stress and strain which may crack the metal. (17-35)
9. To strengthen the area from which the metal was removed. (17-38)
10. Lightening holes are cut in structural units to decrease weight. (17-38)
11. The "minimum bend radius" is the sharpest curve or bend that can be made without critically weakening the part at the bend. (17-45)
12. The length of material needed to make the actual bend. (17-49)
13. They are located at the beginning and end of any bend. (17-64)
14. SB = K (R + T). SB means setback, K is a factor that changes the setback as the angle of bend changes, R stands for the radius of bend, and T represents the thickness of the material. However, to calculate the setback for a 90° bend, the formula is SB = R + T. (17-65–68)
15. The sight line is used to make sure the bend tangent line falls directly under the center of the radius bar of the brake. The sight line is located one radius of the bend from the bend tangent line which is placed under the nose of the brake. (17-69)

Section 18

1. The wing adjustment screws are too tight, which causes excessive clamping pressure. (18-4)
2. The clamping pressure adjustment is made incorrectly and the wing is too tight on one end. (18-4)
3. Adjustments to the bar folder include the thickness adjustment (wing pressure adjusting screws), width adjustment (gage adjusting screw), and angle adjustment (adjustable collar). (18-4, 6, 8)
4. Duplicate bends of 50° may be made with the bar folder by setting the adjustable collar to stop the wing at 50°. (18-8)
5. When the operating handle is raised, the clamping pressure holds the metal securely; therefore, your left hand can be moved away from the folding blade. (18-9)
6. Set the stop gage attached to the bending leaf at the end of the brake to the desired angle. (18-11; Fig. 102)
7. The upper leaf and clamping pressure should be adjusted for the 0.063-inch material. (18-13)
8. Proper adjustments cannot be made to eliminate a creeping top leaf condition unless the cornice brake is level, because an unlevel condition can also be the cause of a creeping top leaf. (18-13)
9. The top leaf was adjusted incorrectly, as one end is closer to the bending leaf than the other end. (18-16)
10. The box and pan brake is best suited to form a standing seam on the four sides. (18-19)
11. The box and pan brake should be used to form the short sides, so they may be formed without distorting the long sides. (18-19)

12. Arcs, circles, and cones. (18-22)
13. To decrease the radius of forming, the rear roll is moved upward. (18-22)
14. The lower rear roll was not adjusted to produce the same radius at both ends of the cylinder. (18-24)
15. Running the metal through the power slip roll former in only one direction was the mistake. Each end of heavy gage material should be rolled a few inches and then the material reversed and fed into the rollers. (18-29)
16. The rust inhibitor should be removed from the rollers and the rollers should be wiped with an oiled rag. (18-30)
17. Some rotary machines have nuts with left-hand threads as well as nuts with right-hand threads; left-hand threads loosen to the right and right-hand threads loosen to the left. (18-34)
18. The horizontal adjustment is not correct; the distance between the side edge and the top roller does not protrude over the shoulder of the bottom roller. (18-36)
19. The metal was not held firmly against the gage as it was rotated through the rolls during the first revolution. (18-39)
20. The pieces to be bent would be scribed 1/8 inch from the edge on the outside of one piece and 1/8 inch from the edge on the inside of the matching piece. (18-41)
21. The crimping machine fabricates crimps that make one piece of pipe smaller so that it will slide into another. Do not crimp the seam, as this will damage the rotary machine. (18-48, 49)
22. The metal was not held straight with the guide. (18-52)
23. The brakehead is lowered by bringing the trip handle forward, then the brakehead is lowered to its lowest position by manually moving the flywheel and then adjusting the holddown tool by placing the metal to be formed between the table and holddown tool and adjusting the holddown tool. (18-54)
24. The foot pedal should be fully depressed while the metal is inserted between the jaws, and the handwheel should be turned to bring the jaws snugly against the material to be formed. (18-59)
25. The arbor press is used as a forming tool. The forming is done by bringing male and female dies together by pressure created through the arbor press ram. (18-62)

Section 19

1. Hammers are made of metal, while mallets are made of hardwood, rubber, plastic, or rawhide. Hammers and mallets are mainly classified by their uses. (19-3–10)
2. Place the metal on a smooth surface, and use light strokes to smooth the irregularities. (19-7)
3. The jaws of the roundnose pliers are wrapped to prevent scarring the metal. When the limitations of the roundnose pliers have been exceeded, crimping pliers are used. The crimping is induced by twisting action rather than clamping action. (19-13, 16)
4. You can use V-blocks or shrinking blocks. (19-24, 27)
5. Formed and extruded types of angles that must be curved (not bent at sharp angles). (19-24)
6. Shaping or forming malleable metal by hammering or pounding it to form a bump. (19-32)
7. The V-block and shrinking block methods. (19-36)
8. The crimping and shrinking block method. (19-38)
9. Stakes are used to form small, odd-shaped pieces and parts, and are used as a backup during finish or planishing work. The hatchet stake is the most appropriate stake to use for hand-forming sharp flanges. (19-39, 48)
10. By a lack of bending response or by "springiness" in the metal. (19-58)
11. In crimping you bend the metal with pliers by rotating the wrist back and forth. (19-63)
12. The nose rib containing relief holes in the outside flange (convex flange) is the easiest to form of the ribs discussed. (19-69; Fig. 121)
13. A form block. (19-80)
14. The sandbag is flexible and time-saving; however, it is difficult to make identical objects with the sandbag because of the sandbags shifting characteristics. (19-81, 88)
15. An offset formed on an angle strip to provide clearance for a sheet or extrusion. (19-92)

Section 20

1. At least 7 times the thickness of the material for soft magnesium alloy, and at least 12 times the thickness of the sheet for hard magnesium alloy. (20-3)
2. Use a blowtorch. (20-8)

STOP— 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 PENCIL.

53450 02 26

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

Chapter 1

1. (200) Ease of attachment is a major factor in selection of aircraft metals. All other factors being equal, advantage may be gained by metal that can be

   a. fiberglassed. c. riveted.
   b. soldered. d. welded.

2. (202) If several different types of metal required heat-treatment, what is the ratio for time that must be used for soaking time that determines if the metal must be soaked separately?

   a. 2 to 1 soaking time differential.
   b. 3 to 1 soaking time differential.
   c. 4 to 1 soaking time differential.
   d. 5 to 1 soaking time differential.

3. (201) The slight variation of a casting alloy is noted in the casting number by the addition of a

   a. letter preceding the alloy number.
   b. letter following the alloy number.
   c. number following the alloy number.
   d. T plus the number of the additional alloy.

4. (201) In the four-digit index system of identifying aluminum alloys, the designation of 7xx indicates the major alloying element is

   a. zinc. c. silicon.
   b. copper. d. magnesium.

5. (200) For metals to meet the specific requirements of aircraft, three factors must be considered. They are

   a. strength, weight, and cost.
   b. strength, weight, and reliability.
   c. ductility, elasticity, and expansion ability.
   d. strength, weight, and corrosion resistance.

6. (201) If a repair figure in a –3 technical order specified a material of 2–24–T3, and the material available for the job was 2024–O, what heat-treatment procedure would be required to obtain the desired material temper?

   a. Artificially aging only.
   b. Solution heat-treatment and quenching in hot water.
   c. Solution heat-treatment, artificially aging, and then quenching in cold water.
   d. Solution heat-treatment and quenching in cold water.

7. (201) The depth of the commercially pure aluminum coating of Alclad or Pureclad is a percentage of the total thickness of the material. This coating is approximately

   a. 5½ percent of the material thickness.
   b. 5½ percent of the material thickness on each side.
   c. 7½ percent of the material thickness on each side.
   d. 11 percent of the material thickness on each side.

8. (202) If during the process of fabrication of non-heat-treatable aluminum the metal becomes too hard to safely form, the way to relieve the stresses is to

   a. anneal the material and let air cool.
   b. artificially age the material to remove old stresses.
   c. reheat-treat the material to stabilize the stresses.
   d. anneal the material and quench rapidly in cold water.

9. (203) In the process of requisitioning material through the Federal Supply System, the index number contains the following: C9500–ML–AF; the –ML– means

   a. master listing.
   b. military logistics.
   c. management data list.
   d. military supply data list.

10. (201) If a piece of metal is marked "QQ–A–250/8, H–38," it would indicate the metal to be

    a. 4130 steel sheet, tempered and normalized.
    b. AR3M magnesium sheet, fully strain-hardened.
    c. 5052 aluminum sheet, fully strain-hardened and stabilized.
    d. 2017 aluminum sheet, solution heat-treated, and cold-worked.

11. (201) If a piece of aluminum alloy tubing is marked with a color code of green, black, green, yellow, a 1-inch space, and then yellow, olive drab, it would indicate the material to be an alloy of

a. 1100-0.
c. 5052-H34.
b. 2024-T3.
d. 7075-T6.

12. (206) Titanium's strength-to-weight ratio is one of the more desirable aspects of using this metal compared to steels. The weight of titanium is approximately

a. 25 percent lighter than aircraft steels.
b. 43 percent lighter than steels used for aircraft.
c. 57 percent lighter than aluminum.
d. the same as steel but titanium is much stronger.

13. (206) If the -3 technical order specified Ti-6A1-4V as the repair material, it would be

a. commercially pure titanium.
b. titanium alloyed with 6 parts aluminum and 4 parts vanadium.
c. titanium alloyed with 6 percent aluminum and 4 percent vanadium.
d. titanium alloyed with 6 tenths of 1 percent aluminum and 4 tenths of 1 percent vanadium.

14. (201) If a technical order specifies QQ-A-250/5-T4, 0.040, it would show the requirement for the metal to be

a. 2024 aluminum, solution heat-treated, 0.040 thickness.
b. 5052 aluminum, solution heat-treated, 0.040 thickness.
c. 2017 aluminum, strain-hardened, stabilized, 0.040 thickness.
d. 7075 aluminum, strain-hardened and artificially aged, 0.040 thickness.

15. (209) If a piece of metal was delivered to the airframe repair shop marked: "CRUCIBLE SAE 4150 MIL-S-18729," these markings would identify the

a. tradename, AISI classification system, Federal specification.
b. crucial steel alloy, ATSM numbering system, military specification.
c. tradename, Society of Automotive Engineers classification, military specification.
d. crucible alloy, ability to withstand hydrochloric acid, Air Force specification number.

16. (202) After aluminum alloy has been soaked at a specific temperature during heat-treatment, it is quenched. This is to prevent the dissolved constituents from

a. age hardening.
b. corroding.
c. going into solid solution.
d. precipitating out of solution.

17. (208) During the ordering of titanium from a supply source, titanium is to be found referenced in supply class code

a. 9515.
c. 9545.
b. 9535.
d. 9550.

18. (205) In the A-B-C classification of titanium, the "C" identifies crystals of

a. heat-treated alpha material.
b. commercially pure titanium.
c. corrosion-resistant titanium alloys.
d. combined alpha and beta alloys.

19. (210) You may furnace reheat-treat nitrided steel without losing any of the case hardness as long as the temperature of the furnace does not exceed

a. 450° Fahrenheit.
b. 650° Fahrenheit.
c. 950° Fahrenheit.
d. 1150° Fahrenheit.

20. (202) In heat-treating clad aluminum, the primary precaution to be taken by the airframe repairman is to

a. prevent long exposure to the heat.
b. insure protective coating is primed.
c. separate clad from nonclad material.
d. insure proper stabilizing conditions.

21. (206) If a sheet of titanium material was delivered to the shop marked: "TIMET TYPE I COMP B GA .040 MIL-T-9046D," the material marking "TYPE I" would indicate the material to be

a. beta phase.
b. alpha phase.
c. alpha-beta phase.
d. commercially pure.

22. (209) If a repair figure specified a material of SAE 1030 steel, what would be the primary alloying element and what percentage of that element would the steel contain?

a. Nickel, 0.30 percent.
b. Carbon, 0.30 percent.
c. Chrome, 0.30 percent.
d. Carbon, 3 percent.

23. (209) Steels containing 0.31 to 0.50 percent carbon are classed as

a. low carbon steels.
b. high carbon steels.
c. a special steel alloy.
d. medium carbon steels.

24. (204) In the shearing process, sheets of aluminum other than 7075–T6 material may be sheared if the material is 0.500 inch or less. In the case of 7075–T6, the limitation on thickness for shearing of sheet is

a. 0.100-inch thickness.
b. 0.200-inch thickness.
c. 0.300-inch thickness.
d. 0.400-inch thickness.

25. (210) A piece of SAE 1040 steel that has been hardened by rapid cooling and is too brittle or harder than desired will have the internal stresses and brittleness reduced by

a. quenching.
b. tempering.
c. normalizing.
d. flame softening.

26. (205) The main advantage of beta alloys over alpha alloys of titanium in the fabrication process is their ability to

a. be heat-treated.
b. be welded.
c. stay free of contamination.
d. withstand heat.

27. (211) When working stainless steels on machines rated for carbon steel, what is the maximum ratio that these machines should be worked?

a. 10 percent of the rated capacity.
b. 30 percent of the rated capacity.
c. 60 percent of the rated capacity.
d. 90 percent of the rated capacity.

28. (212) In applications where metal is rigidly connected and subject to appreciable variation in temperature, a primary concern in using magnesium alloys compared to other metals is the coefficient of thermal expansion. This is critical in the temperature range of

a. 30° to 100° Fahrenheit.
b. 50° to 150° Fahrenheit.
c. 70° to 212° Fahrenheit.
d. 150° to 300° Fahrenheit.

29. (207) If a piece of Type II titanium required a bend radius less than that recommended, what prior procedure would be required?

a. Heating to about 500° Fahrenheit.
b. Heating to about 1240° Fahrenheit.
c. No prior procedures are required.
d. Heat-treating and quenching in oil.

30. (209) For identification, all steel tubular products ¼ inch or more in outside diameter shall be marked in constantly recurring symbols each

a. end within 6 inches of each end.
b. foot of the steel product.
c. 2 feet throughout the product length.
d. 3 feet throughout the product length.

31. (211) When ordering stainless, corrosion-resistant steel through supply, the information and specifications are located in supply class

a. 9510.
b. 9515.
c. 9525.
d. 9530.

32. (213) In the fabrication of a part made of AN–M–30 in the –O condition, bending of a radius of 3 times the sheet thickness would require the metal to be formed

a. in the cold condition.
b. in the cold condition and subsequently annealed.
c. at the elevated temperature of 350° to 800° Fahrenheit.
d. at the elevated temperature of 400° to 700° Fahrenheit and then strain-hardened.

33. (209) The size of the steel ball (brale) normally used when Rockwell testing steels is

a. ¹⁄₁₆ inch in diameter.
b. ⅛ inch in diameter.
c. ¼ inch in diameter.
d. ½ inch in diameter.

34. (213) If during the fabrication of a part using magnesium alloy sheet, the metal required shearing, what additional desired operation would this require of the airframe repairman?

    a. Prescribing the cut line.
    b. Preheating the magnesium to 900° Fahrenheit.
    c. A second shearing to shave approximately $^{1}/_{32}$ inch off the sheared edge.
    d. Adjusting the blade to a minimum clearance of 10 percent of the sheet thickness.

35. (212) If during a repair, the -3 technical order specified a material of AN–M–29. –T4, what would be the Federal specification and temper condition required?

    a. QQ–A–250/5, solution heat-treated and cold-worked.
    b. QQ–M–44, solution heat-treated.
    c. QQ–T–1473B, strain-hardened.
    d. QQ–S18729, artificially aged and then normalized.

36. (213) When riveting magnesium alloys, the recommended rivet to be used, if available, is composed of

    a. 3S aluminum alloy.
    b. 24ST aluminum alloy.
    c. 56S aluminum alloy.
    d. a pure magnesium rivet.

37. (210) To insure a development of hardness in high carbon steel, it must *never* be quenched in

    a. oil.
    b. heated water.
    c. salt brine.
    d. unoiled cold water.

38. (212) The ASTM nomenclature system is used exclusively in designating magnesium and magnesium alloys. The principal alloy elements are indicated by the

    a. numbers.
    b. first two letters.
    c. hypenated suffix.
    d. the numbers preceding the letter X.

39. (211) When you find it necessary to saw thin, light, corrosion-resistant steel with a hand hacksaw, the number of teeth per inch on the blade should be

    a. 14.
    b. 18.
    c. 24.
    d. 32.

40. (212) If a sheet of magnesium alloy is marked: "QQ–M–44 DOW .040 AZ 31B," it would identify the

    a. Federal specification, trademark, thickness, and composition.
    b. military specification, trademark, test method, and composition.
    c. Army-Air Force specification, alloying process, thickness, and composition.
    d. Federal specification, process of development, thickness, and composition.

41. (214) During the requisitioning of magnesium alloy sheet from supply, the information pertaining to the thickness, alloy, content, and heat-treatment is found in supply class

    a. 9505.
    b. 9535.
    c. 9545.
    d. 9555.

42. (214) The heat-treatment that is used to increase the creep strength and retard grain growth of magnesium is termed

    a. annealing.
    b. soaking period.
    c. precipitation heat-treatment.
    d. stabilization heat-treatment.

43. (215) Of the following, which factors must always be considered in the interchangeability of metals?

    a. Strength, weight, contour, and formability.
    b. Weight, contour, strength, and corrosion resistance.
    c. Weight, galvanic potential, contour, and corrosion resistance.
    d. Thickness, corrosive properties, gravity of metal, and formability.

44. (213) When cold bending a radius in magnesium alloy of the annealed condition, the radius of bend should be at least

    a. 3 times the material thickness.
    b. 5 times the material thickness.
    c. 7 times the material thickness.
    d. 9 times the material thickness.

45. (215) Using table 27 of the text, original extrusion number NAS 344–69, substitution would be fabricated with which of the following annealed materials and dimensions?

a. Alclad 2024–O. A. 3.00 inches. B. 1.500 inches. T_1 0.160 inch. T_2 0.160 inch. radius 0.38 inch.
b. Alcald 7075–O. A. 3.00 inches. B. 1.500 inches. T_1 0.160 inch. T_2 0.160 inch. radius 0.38 inch.
c. Alclad 7075–O. A. 3.00 inches. B. 1.500 inches. T_1 0.188 inch. T_2 0.188 inch. radius 0.125 inch.
d. Alclad 2024–O. A. 3.00 inches. B. 1.500 inches. T_1 0.188 inch. T_2 0.188 inch. radius 0.125 inch.

46. (211) When shearing corrosion-resistant steel, clearance between the shear blades is essential to prevent damage to the shear and to produc clean, accurate cuts of metal. This clearance should be approximately

a. 1/20 of the thickness of the material to be cut.
b. 1/30 of the thickness of the material to be cut.
c. 1/40 of the thickness of the material to be cut.
d. 1/2 of the thickness of the material to be cut.

47. (211) Compared to carbon steel, what amount of springback must be allowed for when forming stainless steels by bending with a power brake?

a. 2 to 3 times as much.
b. 3 to 5 times as much.
c. 5 to 7 times as much.
d. None, as springback is the same.

48. (215) A technical order reference calls for 0.040 clad 2024–T36 material to be used in a repair. The only material available for substitution is clad 2014–T6 aluminum. Using table 28 of the text, what would be the multiplying factor used to determine the required thickness of the substitute material?

a. 1.18.
b. 1.43.
c. 1.33.
d. 1.40.

49. (213) When installing magnesium to magnesium, the metal parts should first be protected from corrosion by applying to all faying surfaces one or more coats of

a. lead based paint.
b. lead-zinc primer.
c. chromate pigmented primer.
d. epoxy primer followed by intersurface painting.

Chapter 2

50. (219) What should his answer be if, during a training exercise, you asked a trainee how many 5-pound bags of alkaline cleaner (Type II) are needed to mix 20 gallons of cleaner?

a. 1.
b. 2.
c. 3.
d. 4.

51. (217) Which of the following sequences best describes a typical procedure for inspecting an airframe for corrosion?

a. First inspect the flap well areas, then the empennage, then the fuselage exterior, then the fuselage interior, and then document the noted discrepancies.
b. First inspect the wings, then the wheel wells, then the empennage, then the cockpit area, then the wings' trailing edges, and then document the noted discrepancies.
c. First inspect the wings, then the fuselage exterior, then the empennage, then the fuselage interior, and then document the discrepancies noted.
d. First inspect the wings, then the fuselage, then the control surfaces, then the cockpit, then the empennage, then the wheel well, and then document the discrepancies noted.

52. (219) When aluminum alloy components are found to be stress corroded, how will the corroded area be repaired?

a. Chemically treating the component.
b. Mechanically treating the component.
c. No repair is required on stress corrosion.
d. No repair is authorized on stress corrosion.

53. (220) Black or gray oxides form on titanium alloys when the alloy has been exposed to temperatures at or in excess of

a. 500° Fahrenheit.
b. 1000° Fahrenheit.
c. 1500° Fahrenheit.
d. 2000° Fahrenheit.

54. (221) What is the likely cause if the mixture of phosphoric acid rust remover (Type III) is very weak and is not removing the corrosion?

   a. One part water to one part acid were used.
   b. One part water to two parts acid were used.
   c. Two parts water to two parts acid were used.
   d. Three parts water to one part acid were used.

55. (218) If under working conditions, a piece of zinc is placed into a container of hydrochloric acid, the fumes from this combination could be an asphyxiant. Danger to the individual may also be created due to the fumes also being an

   a. explosive.
   b. anesthetic.
   c. irritant.
   d. acid.

56. (223) How many ounces of chromic acid (CrO_3) are required to make 2 gallons of "chromic acid brush-on solution"?

   a. 1⅓.
   b. 1½.
   c. 1¾.
   d. 2⅔.

57. (220) It is recommended that black or gray oxide on titanium alloys be removed by

   a. chemical methods.
   b. acid pickling method.
   c. mechanical methods.
   d. alkaline water base method.

58. (222) The most likely reaction of aluminum or common steel wool being used to agitate stainless steel type Pasa-Jell is that

   a. a corrosive reaction occurs.
   b. a combustible reaction occurs.
   c. the wool will react by deterioration.
   d. the Pasa-Jell will not react to the stainless steel.

59. (218) To prevent breakage of acid containers, acid will be stored separately from all ignition sources in a

   a. glass container or in a carboy.
   b. fireproof container.
   c. plastic container.
   d. metal container.

60. (221) In using the mechanical method of grit blasting to remove corrosion from ferrous metals, a limitation has been set on the permissible thinness of metal allowed to be severe blasted; this thinness is

   a. 0.032 inch.
   b. 0.050 inch.
   c. 0.0625 inch.
   d. 0.090 inch.

61. (222) Which corrosion removal method should you use to remove minor corrosion from a stainless steel skin that is 0.020 inch thick?

   a. Grinding.
   b. Sand blasting.
   c. Light abrasion.
   d. Abrasive blasting.

Chapter 3

62. (226) If the spindle of the drill press illustrated in figure 39 of the text stops turning with the motor still running, what is the probable trouble?

   a. A slipping chuck.
   b. A broken drive belt.
   c. The index pin is not engaged.
   d. The speed change gears are not engaged.

63. (224) What adjustment has been incorrectly made when production cutting on manually operated squaring shears if the metal is shorter on one side that the other?

   a. One side of the back gage is set incorrectly or has slipped.
   b. The side gage is not adjusted correctly.
   c. The table gage is not adjusted correctly.
   d. Allowance for the metal thickness was not made on one side when setting the gage.

64. (226) Which drill fixture would you be using at its rated capacity to drill a 0.3750-inch diameter hole?

   a. A ¼-inch portable pneumatic drill.
   b. A ⅜-inch portable pneumatic drill.
   c. A ½-inch portable pneumatic drill.
   d. A ½-inch drill press.

65. (225) A job requires a $3\frac{3}{16}$-inch diameter hole which is perfectly round, has clean sides, and has no taper. If the hole saw is chosen to make the hole, what drill fixture will do the job best and with the greatest safety?

   a. A ½-inch drill.
   b. A ¼-inch portable extension drill.

c. A 1/4-inch portable pneumatic drill.
d. A 3/8-inch portable pneumatic drill.

66. (228) If the piece of metal being punched in figure 46 of the text has several holes that are from 1/16 inch to 1/8 inch off the intended location, which operation was probably overlooked?

a. The intended holes were not center punched.
b. The center lines for the holes are too close to the edge of the sheet.
c. The wrong size punch was installed in the Whitney punch.
d. The punch and die of the Whitney punch are out of alignment.

67. (229) When grinding 3/8-inch-thick material on a grinding machine, what is the maximum clearance of the tool rest from the grinding wheel?

a. 1/16-inch.
b. 1/8-inch.
c. 1/4-inch.
d. 3/8-inch.

68. (227) When drilling a hard material such as stainless steel, the included angle of the lip of the twist drill should be ground to an included angle of

a. 59°.
b. 68°.
c. 118°.
d. 136°.

69. (227) What is the decimal equivalent of a 1/8-inch twist drill?

a. 0.1200 inch.
b. 0.1230 inch.
c. 0.1250 inch.
d. 0.1270 inch.

70. (227) If specifications for a hole to be drilled are 0.2500 inch, which twist drills listed in figure 40 of the text can you use?

a. 0.2500-inch or letter F.
b. 0.2500-inch or letter A.
c. 25/1000-inch or letter C.
d. 1/4-inch or letter E.

71. (228) In the process of removing a bolt which is seized in a beam stiffener, in which sequence will the punches listed below be used to remove the bolt?

a. Pin punch, drift punch, starting punch.
b. Center punch, starting punch, drift punch.
c. Starting punch, drift punch, pin punch.
d. Starting punch, center punch, drift punch.

72. (229) The grinding wheels most commonly used by you in an airframe repair shop are composed of abrasives to fit the type of material to be ground; if you had to grind a twist drill of high-speed alloy steel, which abrasive would you select to grind with?

a. Silicate.
b. Silicon carbide.
c. Iron aluminate.
d. Aluminum oxide.

73. (229) What type of file should you select to make a slot 1/8 inch longer in an angle iron bracket 3/16 inch thick?

a. Square file.
b. Mill file.
c. Single-cut file.
d. Overcut file.

Chapter 4

74. (233) Sectional views are used primarily because they

a. explain exteriors.
b. are easy to draw.
c. eliminate hidden lines.
d. show complicated interiors.

75. (230) If the tolerance on a blueprint is an allowable tolerance of 1.374 + .0035 − .0010, the acceptable tolerance is

a. .0010.
b. .0035.
c. .0045.
d. 1.3885.

76. (233) In a multiview drawing, dimensions of a rectangular block are—front 8" x 3" and the end 3" x 6". The top is

a. 3" x 3".
b. 6" x 4".
c. 8" x 6".
d. 3" x 8".

77. (234) The bevel edge of the thimble of a micrometer is marked in 25 equal parts, each equal to

a. 0.001 inch.
b. 0.010 inch.
c. 0.100 inch.
d. 1.000 inch.

78. (235) All of the following layout methods require the use of projection lines except

a. the flat line.
b. the radial line.
c. the parallel line.
d. triangulation.

79. (233) Complex objects with confusing interiors may require a special type drawing called the

a. pictorial view.
b. sectional view.
c. auxiliary view.
d. assembly drawing.

80. (236) The minimum relief hole size permitted in flat sheet metal stock is

a. 1/8 inch.
b. 3/16 inch.
c. 1/4 inch.
d. 5/16 inch.

81. (234) Using a T-square, a 30°–60° triangle, and a 45° triangle in various combinations, all of the following angles can be drawn *except* an angle of

a. 15°.
b. 35°.
c. 75°.
d. 105°.

82. (234) Smooth irregular curves are usually plotted and drawn with

a. a ruling pen.
b. a bow compass.
c. a French curve.
d. an erasing shield.

83. (237) The radius of bend in a sheet of material is the radius of the bend

a. as measured on the inside of the curved material.
b. as measured on the outside of the circle.
c. at its closest point to the outside edge.
d. at its furthermost point of contact.

84. (237) A bend in sheet metal begins at the

a. sight line.
b. mold point.
c. neutral point.
d. bend tangent line.

85. (234) With the combination set complete, the protractor head should be used to draw lines at angles other than

a. 30°.
b. 45°.
c. 60°.
d. 75°.

86. (238) What is adjusted incorrectly on a box and pan brake if one of the fingers extends 1/8 inch beyond the other fingers?

a. The finger.
b. The upper beam.
c. The thumb screw.
d. The bending leaf.

87. (235) In triangulation, the hypotenuse of a right triangle is used to find the

a. length of the stretchout.
b. true height of the object.
c. length of the surface element lines.
d. true width of the object.

88. (234) On a micrometer, the horizontal line on the barrel reads 1/10 inch; the visible graduations on the thimble read more than 0.020 inch and less than 0.021 inch. On the vernier scale, the number 7 coincides with a line on the thimble; this gives a total measurement of

a. 0.0127.
b. 0.1270.
c. 0.1207.
d. 1.0270.

89. (238) During the operation of the cornice brake, the upper leaf creeps. If proper adjustment of the lead does *not* prevent creeping, the next logical step is to

a. level the machine.
b. adjust the bed ends.
c. adjust the bending leaf.
d. level the centering bar at both ends.

90. (237) By using table 39 of the text, the bend allowance of a piece of metal with a sheet thickness of 0.081 inch, a radius of bend of 0.125 inch, and a bend of 140° is calculated to be

a. 0.002813 inch.
b. 0.003156 inch.
c. 0.253 inch.
d. 0.39382 inch.

91. (234) After adding an inch seam allowance, the stretchout for a duct measuring 6 inches in diameter and 10 inches in length would be approximately

a. 10.4 inches.
b. 11.0 inches.
c. 19.8 inches.
d. 32.4 inches.

92. (236) The edge of a lightening hole is often stretched to

a. provide clearance for an extrusion.
b. form a beveled reinforcing edge.
c. make the part fit the job.
d. make it balloon.

93. (240) The leverage applied to the handle of the hand-operated arbor press is transmitted to the work piece through the

a. ram, to the rack, to the pinion gear.
b. male die, to the ram, to the pinion gear.
c. rack, to the chain assembly, to the ram.
d. pinion gear, to the rack, to the ram, to the male die.

94. (237) When forming radius bends, you must consider the thickness of the material, its alloy composition, and

a. its malleability.
b. its temper condition.
c. the ductility of the material.
d. its annealing characteristics.

95. (238) During the folding operation, raising the handle affects the holding jaw of the bar folder in what way?

a. Raises it.
b. Lowers it.
c. Starts it forward.
d. Starts it rearward.

96. (239) When using the slip roll former, the contour on the metal is formed by the

a. top roll.
b. rear roll.
c. front roll.
d. bottom roll.

97. (240) Which of the following is best suited to turn an edge on a 90° rectangular elbow which will be assembled with Pittsburg lock seams?

a. The turning machine.
b. The beading machine.
c. The burring machine.
d. The elbow edging machine.

98. (239) A conical shape can be formed with the slip roll former by

a. setting the back roll at an angle.
b. using the grooved portion of the rolls.
c. feeding the metal through the rollers on a diagonal.
d. reversing the metal after each pass through the rollers.

99. (242) Which of the operations given below are all forming operations?

a. Bumping, stretching, bending, and flanging.
b. Stretching, shrinking, crimping, and bending.
c. Bumping, stretching, shrinking, and scribing.
d. Crimping, stretching, shrinking, and bumping.

100. (239) If a power-operated slip roll forming machine has a capacity of ⅛-inch thickness and has an upper roll 48 inches long with a 4-inch diameter, what is the smallest diameter cylinder that can be formed from ⅛-inch steel 48 inches long?

a. 4 inches.
b. 8 inches.
c. 12 inches.
d. 16 inches.

101. (235) The radius of the stretchout arc in the pattern for a regular cone is always equal to the

a. radius of the plan view.
b. diameter of the plan view.
c. slant height of the elevation view.
d. actual height of the elevation view.

102. (240) Prior to operation of the power flanging machine, the adjustment for thickness of material is made by the

a. horizontal adjustment.
b. vertical adjustment.
c. brake head.
d. type of hold-down tool.

103. (240) What position should the foot lever of the stretching and shrinking machine be in while adjusting the dies for material thickness?

a. Full stroke.
b. Neutral position.
c. Locked position.
d. Negative stroke.

104. (241) If the following pliers are available to use for crimping a thin piece of sheet metal, which should you select?

a. Half roundnose.
b. Roundnose.
c. Flatnose.
d. Dikes.

105. (241) You are assigned the task of tucking the edges of a sheet of metal stock. Which of the following would you select to do the job properly?

a. Setting hammer.
b. Riveting hammer.
c. Stretching hammer.
d. Planishing hammer.

106. (242) The wooden block designed for bumping should have the same contour and dimensions as the

a. stretched outside of the blister.
b. shrunken outside of the blister.
c. stretched inside of the blister.
d. shrunken inside of the blister.

107. (242) In the forming or reshaping of a piece of tubing, which of the following forming stakes should be selected to do the job?

a. Hollow mandrel or hatchet.
b. Candlemold or needlecase.
c. Beakhorn or blowhorn.
d. Roundhead or bottom.

108. (243) To curve a formed angle which has wide flanges, use

a. V-blocks.
b. joggle blocks.
c. forming blocks.
d. shrinking blocks.

109. (240) During the operation of the power flanging machine, higher speeds should *not* be attempted until the flange is formed to approximately

a. 40°.	c. 60°.
b. 50°.	d. 70°.

110. (244) At the intersection of a stringer and a former, you will often find a

a. bolt.	c. rivet.
b. bend.	d. joggle.

53450 03 7112

CDC 53450

AIRFRAME REPAIR SPECIALIST

(AFSC 53450)

Volume 3

Aircraft Structural Repairs

2-3

Extension Course Institute

Air University

Contents

		Page
	Preface	*iii*
Chapter		
1	TECHNICAL ORDERS	1
2	AIRCRAFT FASTENERS	15
3	COMMON ATTACHING METHODS	55
4	STRUCTURAL REPAIR	67
5	CONTROL SURFACE BALANCING	103

Preface

THIS VOLUME of CDC 53450 reviews the technical order numbering system and the use of technical orders to locate information needed to repair aircraft structures. Volume 3 also discusses how different fastening devices, such as rivets, huck lockbolts, turnloc fasteners, sheet metal screws, nuts, bolts, and washers, are used in repairing aircraft structures. The principles involved in using sealants and smoothing compounds while repairing damaged aircraft structures are also discussed. Finally, information you need for balancing control surfaces after repairs have been accomplished is also included in the volume.

Remember, specific procedures for accomplishing aircraft structural repairs and maintenance of tools and equipment must be in accordance with applicable maintenance manuals.

The number which appears on the figures in this volume (for example 53450-3-2-1) represents the preparing agency's illustration file number.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC), Chanute AFB IL 61868.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, Alabama 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 30 hours (10 points).

Material in this volume is technically accurate, adequate, and current as of September 1971.

* NOTE: Page 276 was removed due to deleted material. No pertinent information was omitted.

MODIFICATIONS

Chapter 1 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

279

Aircraft Fasteners

FOR YEARS YOU have been fastening things together. You fasten the left side of your shirt to the right side with a device known as a button. You really don't "button up the aircraft," but, as you know, certain fastening devices are used to hold panels, fairing, cowling, patches, etc., on the aircraft. In this chapter we will discuss aircraft fasteners and how they are used; also, the tools you use to install the fastening devices. Upon the completion of this chapter, you should be able to identify the types of fastening devices and the various tools you use to install them.

6. Rivet Identification

6-1. An aircraft, even though made of the best materials and strongest parts, would be useless unless those parts were firmly held together. Several methods are used to hold metal parts together; they include riveting, bolting, and welding. The process that is used must produce a union that will be as strong as, or stronger than, the parts that are joined.

6-2. A rivet is a metal pin used to hold two or more metal sheets, plates, or pieces of material together. A head is formed on one end when the rivet is manufactured. The shank of the rivet is placed through matched holes in two pieces of material. The tip is then mushroomed to form a second head to clamp the two pieces securely together. The second head, formed either by hand or by pneumatic equipment, is called a shop head; it serves the same purpose as a nut on a bolt.

6-3. Thousands of rivets are necessary in the building of modern aircraft. More than 150,000 rivets are required in constructing a medium bomber, and nearly half a million in a large bomber. These figures indicate the importance of rivets and riveting. As an airframe repairman, you must be a skilled riveter and have a thorough knowledge of the various types of rivets and their uses. You must be able to identify head shapes and alloy composition and to select the correct rivet for a given job.

6-4. Many types of rivets are available. A type exists for nearly every location and kind of structural stress you may encounter. Rivets are divided into two main groups: common solid-shank rivets and special rivets, the latter being used in special cases.

6-5. Solid-shank rivets are generally used in repair work. They are identified by the kind of material of which they are made, head type, size of shank, and temper condition. The designation of the solid-shank rivet head type, such as universal-head and countersunk-head, depends on the cross-sectional shape of the head. The temper designation and probable strength are indicated by special markings on the head of the rivet, as shown in table 1.

6-6. **Materials.** The material used for most aircraft solid shank rivets is aluminum alloy. The strength and temper conditions of these rivets are identified by digits and letters similar to those adopted for the identification of strength and temper conditions of aluminum and aluminum alloy sheet stock. The 1100, 2017–T4, 2024–T4, 2117–T4, and 5056 rivets are the five grades usually available.

6-7. The 1100 rivet, which is composed of 99.00 percent pure aluminum, is very soft. It is used for riveting the softer aluminum alloys which are used for nonstructural parts (all parts where strength is not a factor). The riveting of map cases is one example of its use.

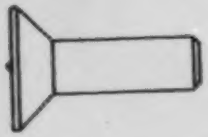
6-8. The 2117–T4 rivet, known as the field rivet, is used more than any other rivet for riveting aluminum alloy structures. The field rivet is in wide demand because it is ready for use as received and needs no further heat-treating or annealing. It also has a high resistance to corrosion.

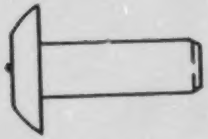
6-9. The 2017–T and 2024–T4 rivets are used where more strength is needed than is obtainable with the 2117–T4 rivet. The 5056 rivet is for riveting magnesium alloy structures. It has a high corrosion-resistant quality, but its shear and bearing strength is very low.

289

TABLE 1
RIVET IDENTIFICATION TABLE

MS20426
MS20427
100 DEGREE
COUNTERSUNK
HEAD





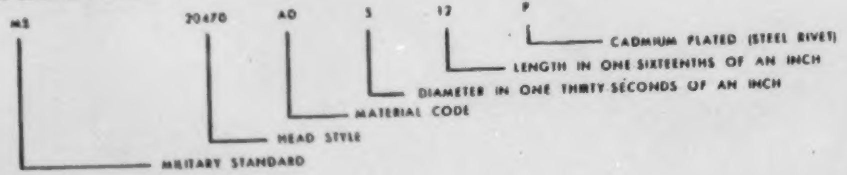
MS20470
MS20613
MS20615
UNIVERSAL
HEAD

MATERIAL	HEAD MARKING	MS MATERIAL CODE	MS20426 CSK HEAD	MS20427 CSK HEAD	MS20470 UNIV HEAD	MS20613 UNIV HEAD	MS20615 UNIV HEAD	HEAT TREAT BEFORE USING	STRENGTH (PSI)	
									SHEAR	BEARING
1100	PLAIN ○	A	X		X			NO	10000	25000
2117	DIMPLED ⊙	AD	X		X			NO	30000	100000
2017	RAISED TEAT ⊙	D	X		X			YES	34000	113000
2024	RAISED DOUBLE DASH ⊜	DD	X		X			YES	41000	136000
5056	RAISED CROSS ⊕	B	X		X			NO	27000	90000
CARBON STEEL	RECESSED TRIANGLE △			X		X		NO	35000	90000
CORROSION RESISTANT STEEL	PLAIN ○	F		X		X		NO	75000	90000
MONEL, FEDERAL SPECIFICATION QQ N 281	RECESSED DOUBLE DIMPLE (••)	M		X			X	NO	55000	
COPPER, FEDERAL SPECIFICATION QQ W 341	PLAIN ○	CU		X			X	NO	25000	

54 138

NOTES

1. THE PREDOMINATING COLOR OF LABELS FOR BOXES OF MS RIVETS ARE AS FOLLOWS (MILITARY SPECIFICATION, MIL R 5674) 1100 WHITE, 2017 YELLOW, 2117 ORANGE, 5056 BLUE
2. ALL STRENGTH CALCULATIONS FOR RIVETS SHOULD BE BASED ON DIAMETER OF RIVET
3. RIVET SPECIFICATION MIL R 5674, COVERS MATERIALS TYPES A, AD, B D, AND DD LISTED ABOVE. ALL ALUMINUM ALLOY RIVETS ARE ANODIZED
4. AN EXAMPLE RIVET NUMBER CODE IS AS FOLLOWS


MS
20470
AD
5
12
F
CADMIUM PLATED (STEEL RIVET)
LENGTH IN ONE SIXTEENTHS OF AN INCH
DIAMETER IN ONE THIRTY SECONDS OF AN INCH
MATERIAL CODE
HEAD STYLE
MILITARY STANDARD

280

6-10. **Mild steel** rivets are used for riveting steel parts. The corrosion-resistant steel rivets are for riveting corrosion-resistant steel in firewalls, exhaust stack brackets, and similar structures.

6-11. Monel rivets are used for riveting nickel-steel alloys. They can be substituted for those made of corrosion-resistant steel in some cases.

6-12. The use of copper rivets in aircraft repair is limited. Copper rivets can be used only on copper alloys or nonmetallic materials such as leather.

6-13. **Heat-Treating of Ice Box Rivets.** Temper is an important factor to the riveting process, especially with aluminum alloy rivets. Such rivets have the same heat-treating characteristics as aluminum alloy sheet stock. They can be hardened and annealed in the same manner as sheet aluminum. The rivet must be soft, or comparatively soft, before a good shop head can be formed. The 2017 and 2024–T4 rivets are ~~annealed~~ heat treated before being driven. They harden with age.

6-14. The process of heat-treating (~~annealing)~~ rivets is much the same as that of sheet stock. An electric air furnace, a salt bath, or a hot oil bath is needed. Depending on the alloy, the heat-treating range is 910° to 950° Fahrenheit (F). For convenient handling, rivets are heated in a tray or a wire basket. They are quenched in cold water (70° F) immediately after heat-treating.

6-15. The 2017- and 2024–T4 rivets, which are heat-treatable, begin to age-harden within a few minutes after they are exposed to room temperature. Therefore, they must be used immediately after quenching or be placed in cold storage. The most common method used for storing heat-treatable rivets at low temperature (below 32° F.) is an electric refrigerator. These rivets are referred to as "icebox" rivets. Under this storage condition, they will remain soft enough for driving for periods up to 2 weeks. Any rivets not used within that time should be removed for reheat-treating.

6-16. Icebox rivets attain about one-half of their maximum strength in approximately 1 hour after driving and full strength in about 4 days. When 2017–T4 rivets are exposed to room temperature for 1 hour or longer, they must be reheat-treated. This also applies to 2024T rivets exposed to room temperature for a period exceeding 20 minutes.

6-17. Once an icebox rivet has been taken from the refrigerator it should not be mixed with the rivets still in cold storage. If more rivets are removed from the icebox than can be used in 20 minutes, they should be placed in a separate container and stored for reheat-treating. Heat treatment of rivets may be repeated a number of times if done properly. Proper heating times and temperatures are as follows:

Heating Time—Air Furnace

Rivet Alloy	*Time at Temperature*	*Heat-Treating Temperature*
2024–T4	1 hour	910° to 930° F.
2017–T4	1 hour	925° to 950° F.

Heating Time—Salt Bath

2024–T4	30 minutes	910° to 930° F.
2017–T4	30 minutes	925° to 950° F.

6-18. Reheating an excessive number of times will result in a gradual hardening of the rivets. Fifteen or more times is considered excessive. Earlier, you were shown the heating and quenching equipment for heat-treating rivets. Rivets coated for corrosion resistance are never heated in a salt bath.

6-19. The head markings will identify the composition of a rivet, whether it is heat-treatable or not. If the markings are not distinct, the hardness of the rivet can be determined by using the Rockwell hardness test described previously. To use this machine, place the rivet on a V-block anvil, use the $\frac{1}{16}$-inch ball penetrator, and apply a 60-kilogram load. A reading of 75 or over on the B scale indicates an age-hardened and heat-treatable rivet.

6-20. **Corrosion Resistance.** This factor must be considered when choosing aircraft rivets. Almost all metals, and therefore aircraft rivet stock, are subject to corrosion. As discussed earlier, corrosion may be the result of local climate conditions and/or the fabrication process used. It is reduced to a minimum by using metals which are highly resistant to corrosion and possess the correct strength-to-weight ratio. Avoid the use of dissimilar metals whenever possible. To comply with military standards (MS) the manufacturers must put a protective surface coating on the rivets. This may be zinc chromate, metal spray, or an anodized finish. The protective coating on a rivet is identified by its color. A rivet coated with zinc chromate is yellow, an anodized surface is pearl gray, the metal-sprayed rivet is identified by a silvery gray color. If an emergency arises where a protective coating must be applied on the job, paint the rivet with zinc chromate before it is used and again after it is driven.

6-21. Ferrous metals placed in contact with moist salt air begin to rust if not properly protected. Nonferrous metals, those without an iron base, do not rust, but corrosion takes place. The salt in moist air, as found in the coastal areas, attacks the aluminum alloys. It is a common experience to inspect the rivets of an aircraft that has been stationed at a coastal base and find them badly corroded. This is another example of corrosion caused by the geographic location of operations.

6-22. If a copper rivet is inserted into an aluminum alloy structure, two dissimilar metals will be brought in contact with each other. Remember, all metals possess a small electrical potential. Two dissimilar metals in contact with each other in the presence of moisture cause an electrical current to flow. This will cause corrosion and the dissolution of one of the metals.

6-23. Certain aluminum alloys react to each other and, therefore, must be considered as dissimilar metals. The commonly used aluminum alloys may be divided into the two groups as follows:

Group A—1100, 3003, 5052, and 6053
Group B—2017, 2024, 2117, and 7075

6-24. Members of either group A or group B can be considered as similar to each other and will not react to others within the same group. A corroding action will take place, however, if any metal of group A comes in contact with a metal in group B in the presence of moisture.

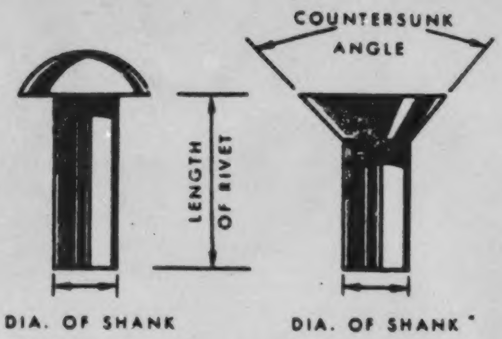
6-25. Rivets are manufactured in several different head styles: roundhead, flatheat, brazier-head, universal head, and countersunk head.

6-26. The universal head is a combination of the roundhead, flathead and brazier-head, all of which have protruding heads. It is used in aircraft construction and repair in both interior and exterior locations. When protruding head rivets must be replaced, they can be replaced with universal-head rivets.

6-27. The countersunk-head rivet is flat topped and beveled toward the shank. It will fit into a countersunk or dimpled hole and lie flush with the surface of the material. The angle at which the sides slope may vary from 78° to 120°. Gradually, manufacturers are standardizing on the 100° countersunk head. These rivets are used to fasten sheets over which other sheets must fit. They are also used on exterior surfaces of the aircraft because they offer only slight resistance to the slipstream and help minimize turbulent airflow.

6-28. **Head Markings.** The markings on the heads of rivets indicate the material of which they are made and their strength. Table 1 identifies the rivet head markings and the materials of which they are made. You will notice there are three materials indicated by a plain head; yet, it is possible to distinguish their difference by color. The 1100 is aluminum color; the mild steel is a typical steel color; and the copper rivet is a copper color. Any head marking can appear on any head style of the same material.

6-29. Different markings on the heads of rivets are also used to classify their characteristics. These markings may be either a raised teat, a dimple, a pair of raised dashes, a raised cross, a single triangle, some rivet heads have no markings. The different markings indicate the composition of the rivet stock. The rivets are also different in color. This was explained previously as a means of identifying the protective surface coating used by the manufacturer.



53450-3-2-1

Figure 1. Methods of measuring rivets.

6-30. **Code Number.** Each type of rivet is identified by a part number so that you will be able to select the proper rivet for the job. These part numbers are in series, and each series represents a particular type of head. For example, the part number MS20426 means that the rivet is a military standard and has a 100° countersunk head.

6-31. There are also letters and numbers added to a part number. The letters designate alloy content; the numbers, rivet diameter and length. A letter, or letters, following the basic military standard (MS) number indicates the rivet material composition. The absence of a letter indicates that the rivet is manufactured from carbon or mild steel. The first dash number designates diameter of the rivet in thirty-seconds of an inch, and the second dash number designates the length of the rivet in sixteenths of an inch. An example of a complete rivet part number is shown in table 1. The methods for measuring rivets are shown in figure 1.

6-32. Aluminum and aluminum alloy rivets are also packaged in boxes bearing colored labels. The color of the label will indicate the composition of the rivets inside the box. The rivets and the corresponding label color are 1100, white; 2117-4, orange; 2017-T4, yellow; 2024-T4, red; and 5056, blue.

7. Pneumatic Riveter.

7-1. The most common upsetting tool used in airframe repair work is the slow hitting pneumatic hammer called a rivet gun. Pneumatic guns, or riveters, are available in various sizes and shapes.

Figure 2 is a drawing of these shapes. The capacity of each gun, as recommended by the manufacturer, is usually stamped on the barrel. Pneumatic guns operate on air pressure of 90 to 100 pounds per square inch.

7-2. Pneumatic guns are used in conjunction with interchangeable rivet sets. Each set is designed to fit the type of rivet and location of the work. The shank of the set is designed to fit into the rivet gun. In figure 3 you can see that the force to buck the rivet is supplied by the air-driven hammer inside the barrel of the gun. The sets are made of high-grade carbon-tool steel and are heat-treated to give them strength and the ability to withstand wear.

7-3. Some of the precautions to be observed when using a rivet gun are:

a. Never point the gun at anybody at any time. It is a rivet gun (not a 0.45) and is to be used for one purpose—to drive or install rivets.

b. Never depress the trigger mechanism unless the set is held tightly against a block of wood or a rivet.

c. Never use the rivet gun as a toy. It is not a plaything but a tool to use in the right way to perform a job.

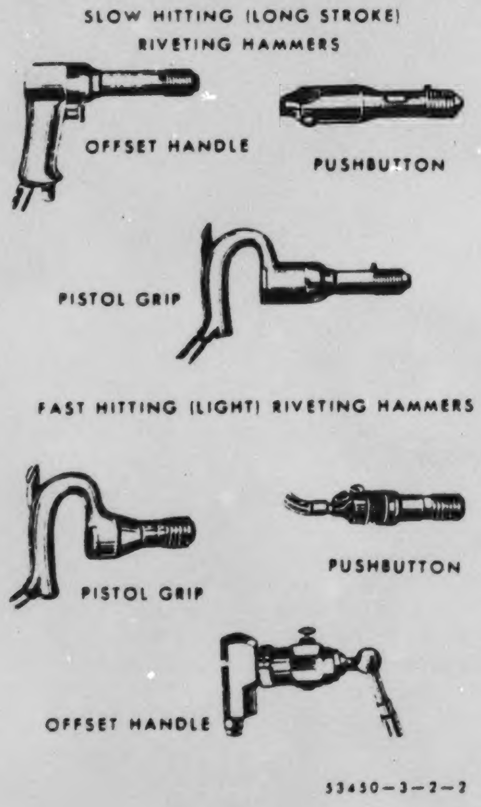

SLOW HITTING (LONG STROKE) RIVETING HAMMERS
OFFSET HANDLE
PUSHBUTTON
PISTOL GRIP
FAST HITTING (LIGHT) RIVETING HAMMERS
PISTOL GRIP
PUSHBUTTON
OFFSET HANDLE
53450-3-2-2

Figure 2. Types of rivet guns.

d. Always disconnect the air hose from the rivet gun when it will not be in use for any appreciable length of time.

7-4. Sometimes it is necessary to use the squeeze method of riveting. This method is limited since it can be used only over the edges of sheets or assemblies where conditions permit, and where the reach of the squeeze riveter is deep enough.

7-5. Rivet squeezers are of three types: hand, pneumatic and pneudraulic. They are basically alike except that in the hand rivet squeezer, compression is supplied by hand pressure; in the pneumatic rivet squeezer, by air pressure; and in the pneudraulic, by a combination of air and hydraulic pressure. One jaw is stationary and serves as a bucking bar; the other jaw is movable and does the upsetting. Riveting with a squeezer is a quick method and requires only one operator.

7-6. Squeeze riveters are usually equipped with either a C yoke or an alligator yoke. Yokes are available in various sizes to accommodate any size of rivet. The working capacity of a yoke is measured by its gap and its reach. The gap is the distance between the movable jaw and the stationary jaw; the reach is the inside length of the throat measured from the center of the end sets.

7-7. End sets for squeeze riveters serve the same purpose as rivet sets for pneumatic rivet guns and are available with the same type heads. They are interchangeable to suit any type of rivet head. One part of each set is inserted in the stationary jaw, while the other part is placed in the movable jaws. The manufactured head end set is placed on the stationary jaw whenever possible. However, during some operations, it may be necessary to reverse the end sets, placing the manufactured head end set on the movable jaw.

7-8. Before you use the pneumatic riveter, drop one or two drops of oil in the air inlet. This is the only way you can get oil to all moving parts. Set the regulator adjustment screw to the position for proper operation of the riveter. Select the rivet set for the job and install the set in the barrel of the riveter.

8. Rivet Installation

8-1. Performance of any repair requiring the use of rivets will confront you with four major phases of the problem: selection of the proper rivet, layout of the rivet pattern, preparation of rivet holes, and upsetting the rivet. Earlier, you studied the identification of rivets; now we will continue our study of aircraft fasteners by discussing rivet layout.

8-2. **Rivet Layout.** Rivet layout consists of determining the number of rivets required; the size and style of rivet to use; the material, temper

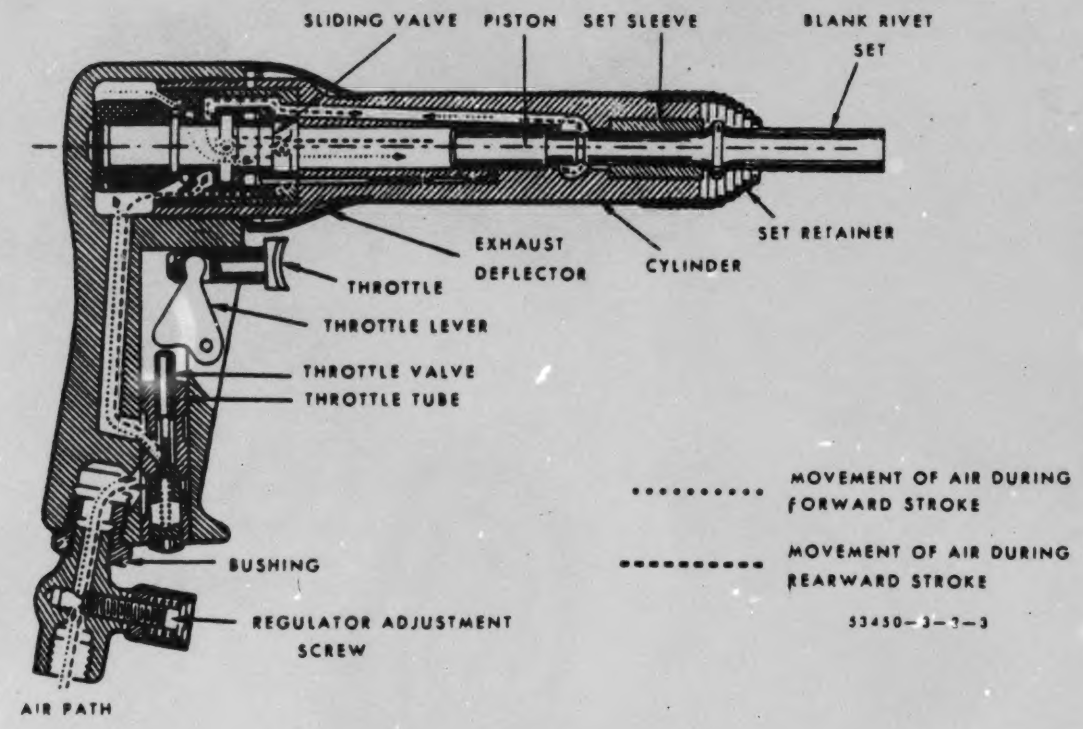

SLIDING VALVE
PISTON
SET SLEEVE
BLANK RIVET SET
SET RETAINER
EXHAUST DEFLECTOR
CYLINDER
THROTTLE
THROTTLE LEVER
THROTTLE VALVE
THROTTLE TUBE
BUSHING
REGULATOR ADJUSTMENT SCREW
AIR PATH
MOVEMENT OF AIR DURING FORWARD STROKE
MOVEMENT OF AIR DURING REARWARD STROKE
53450-3-3-3

Figure 3. Rivet gun nomenclature.

condition, and strength of the rivet; the size of the rivet holes; distance of the rivet holes and rivets from the edges of the patch; and the spacing of rivets throughout the repair. Since distances are measured in terms of rivet diameters, application of the measurements is simple once the correct rivet diameter is determined.

8-3. Single-row, two-row, and three-row layouts designed for small repair jobs are discussed in this chapter. More complicated layouts for large repairs, which require the application of rivet formulas, are discussed later.

8-4. *Selection.* The type of head, size, and strength required in a rivet are governed by such factors as the kind of forces present at the point riveted, the kind and thickness of the material to be riveted, and location of the riveted part on the aircraft.

8-5. The type of head required for a particular job is determined by its installation location. Where a smooth aerodynamic surface is required, countersunk head rivets should be used. Universal-head rivets may be used in most other locations. If extra strength is required and clearance permits, roundhead rivets may be used; if the necessary clearance is not available, flathead rivets may be used.

8-6. The size (or diameter) of the selected rivet shank should correspond in general to the thickness of the material being riveted. If you use too large a rivet in a thin material, the force necessary to drive the rivet properly will cause an undesirable bulging around the rivet head. On the other hand, if you select too small a rivet diameter for thick material, the shear strength of the rivet will not be great enough to carry the load of the joint. As a general rule, the rivet diameter should not be less than the combined thickness of the component parts of the joint. Rivets most commonly chosen in the assembly and repair of aircraft range from $\frac{3}{32}$ inch to $\frac{3}{8}$ inch in diameter. Ordinarily, rivets smaller than $\frac{3}{32}$ inch in diameter are never used on any structural parts which carry stresses.

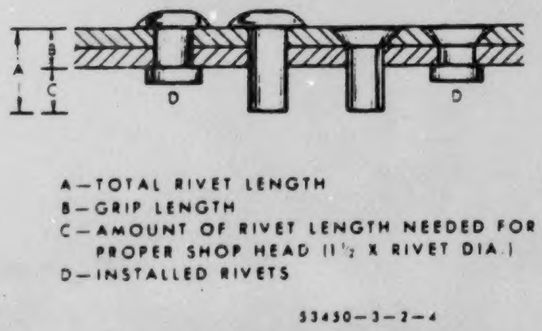

A
B
C
D
D
A—TOTAL RIVET LENGTH
B—GRIP LENGTH
C—AMOUNT OF RIVET LENGTH NEEDED FOR PROPER SHOP HEAD (1½ X RIVET DIA.)
D—INSTALLED RIVETS
53450-3-2-4

Figure 4. Determining length of rivet.

8-7. When rivets are to pass completely through tubular members, select a rivet diameter equivalent to at least one-eighth the outside diameter of the tube. If one tube "sleeves" or fits over another, take the outside diameter of the outside tube and use one-eighth of that distance as the minimum rivet diameter. A good practice is to calculate the minimum rivet diameter and then use the next larger size rivet.

8-8. When determining the total length of a rivet for installation, the combined thickness of the materials to be joined must be known. This measurement is known as grip length and is illustrated in B of figure 4. The total length of the rivet (see A of fig. 4) should be equal to grip length plus the amount of rivet shank necessary to form a proper shop head. The length of rivet required to form a shop head is 1½ times the diameter of a rivet shank, as illustrated in C of figure 4.

8-9. Using figure 4 and the above information, we determine that A = B + C. (A, total rivet length; B, grip length; C, material needed to form a shop head.)

8-10. Properly installed rivets are shown as D in figure 4. Note carefully the method used to measure total rivet lengths for countersunk rivets and the other type of head.

8-11. You may determine the type of rivet-head to select for a particular repair job by referring to the type used within the surrounding area by the manufacturer. A general rule to follow on a flush-riveted aircraft is to apply flush rivets on the upper surface of the wing and stabilizers, on the lower leading edge back to the spar, and on the fuselage back to the high point of the wing. Use universal-head rivets in all other surface areas.

8-12. *Spacing.* In general, try to make the spacing of the rivets on a repair conform to that used by the manufacturer in the area surrounding the damage. Aside from this fundamental rule, there is no specific set of rules which governs spacing of rivets in all cases. However, there are certain minimum requirements which you must observe.

8-13. The edge distance, or distance from the center of the first rivet to the edge of the sheet, should be not less than 2 rivet diameters nor more than 4. The recommended edge distance is about 2½ rivet diameters. If you place rivets too close to the edge of the sheet, the sheet is likely to crack or pull away from the rivets: and if you space them too far from the edge, the sheet is apt to turn up at the edges.

8-14. Rivet pitch is the distance between the centers of neighboring rivets in the same row. The smallest allowable rivet pitch is 3 rivet diameters. The average rivet pitch usually ranges from 6 to 8 rivet diameters, although rivet pitch may range from 4 to 10 rivet diameters. Transverse pitch is the perpendicular distance between the rivet rows; it is usually equal to 75 percent of the rivet pitch. The smallest allowable transverse pitch is 2½ rivet diameters.

8-15. When splicing a damaged tube where the rivets pass completely through the tube, space the rivets 4 to 7 rivet diameters apart if neighboring rivets are at right angles to each other, and space them 5 to 7 rivet diameters apart if the rivets are in line (parallel to each other). The first rivet on each side of the joint should not be less than 2½ rivet diameters from the end of the sleeve.

8-16. The general rules of rivet spacing, as applied to straight-row layout, are quite simple. In a single-row layout, first determine the edge distance at each end of the row and then lay off the rivet pitch (distance between rivets) as shown in figure 5. In the two-row layout, lay off the first row as

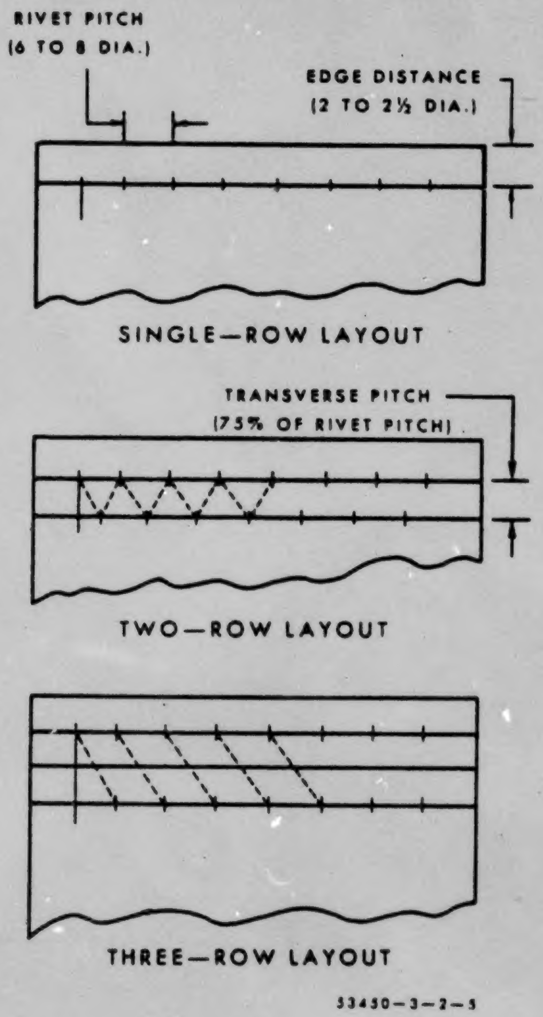


Figure 5. Rivet spacing.

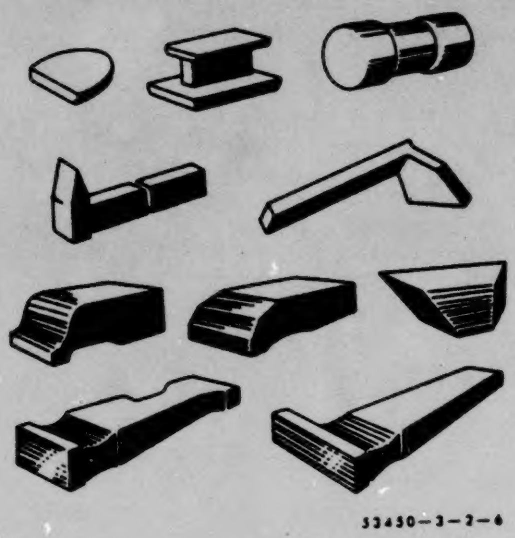


Figure 6. Bucking bars.

just described, place the second row a distance equal to the transverse pitch from the first row, and then lay off rivet spots in the second row so they fall midway between those in the first row. In a three-row layout, lay off the first and third rows, and then determine the second row rivet spots by using a straight edge. (See fig. 5.)

8-17. **Equipment.** The various tools needed in the normal course of driving and upsetting rivets include drills, reamers, rivet cutters or nippers, bucking bars, riveting hammers, draw sets, dimpling dies or other type of counterinking equipment, rivet guns, and squeeze riveters. Self-tapping screws, C-clamps, and fasteners are riveting accessories commonly employed to hold sheets together when riveting.

8-18. Tools and equipment needed in the installation of rivets are discussed in the following paragraphs.

8-19. *Hole duplicators.* When sections of skin are replaced with new sections, the holes in the replacement sheet or in the patch must be drilled to match existing holes in the structure. These holes can be located with a hole duplicator. The peg on the bottom leg of the duplicator fits into the existing rivet hole. The hole in the new part is made by drilling through the bushing on the top leg. If the duplicator is properly made, holes drilled in this manner will be in perfect alignment. A separate duplicator is used for each diameter of rivet.

8-20. *Rivet cutters.* In case you cannot obtain rivets of the required length, rivet cutters can be used to cut rivets to the desired length. When using the rotary rivet cutter, insert the rivet in the correct hole, place the required number of shims under the rivet head, and squeeze as you would a pair of pliers. Rotation of the discs will cut the rivet to give the right length (as determined by the number of shims inserted under the head). When using the large rivet cutter, place it in a vise, insert the rivet in the proper hole, and cut by pulling the handle, thus shearing off the rivet. If regular rivet cutters are not available, diagonal cutting pliers can be used as an emergency cutter.

8-2. *Bucking bars.* A bucking bar is a tool which is held against the shank end of a rivet while the shop head is being formed. Most bucking bars are made of alloy bar stock; but those made of better grades of steel last longer and require less reconditioning. Bucking bars are made in a number of different shapes and sizes to facilitate rivet bucking in all places where rivets are used. Some of the various bucking bars are shown in figure 6.

8-22. The bars must be kept clean, smooth, and well polished. Their edges should be slightly rounded to prevent your marring the material surrounding the riveting operation. The face of the bar is usually concave to conform to the shape of the shop head to be made. The face should have a radius slightly larger than the thin head to insure solid bucking and to prevent marring the material to be riveted. Six pounds is the average weight of the bucking bars. These bars are sometimes called "dollies," "bucking irons," or "bucking blocks."

8-23. Inaccessible areas require special bars to accomplish the riveting operation. The *expanding bucking bar,* drawn in figure 7, is such a tool. It is a steel block whose diameter or width can be adjusted. It is attached to the end of a hollow steel shaft which contains a bar that can be twisted to expand or reduce the width of the block. It is used to buck rivets on the inside of tubular structures or in similar spaces that cannot be reached by regular bucking bars. The space must be small enough for one side of the partially expanded block to press against the tip of the rivet's shank and for the other side to press against a strong supporting surface. Expanding bucking bars speed up the process of riveting the skin on wing sections.

8-24. *Hand rivet and draw sets.* A hand rivet set is a tool equipped with a die for driving a par-

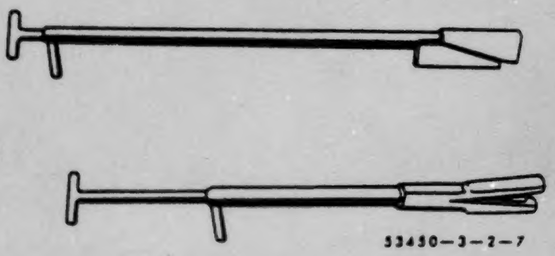


Figure 7. Expanding bucking bars.

ticular type rivet. Rivet sets are available to fit every size and shape of rivet head. The ordinary set is made of ½-inch carbon tool steel about 6 inches long and is knurled to prevent slipping in the hand. Only the face of the set is hardened and polished.

8-25. Sets for round-head and brazier-head rivets are recessed (or cupped) to fit the rivet head. In selecting the correct set, be sure that it will provide the proper clearance between the set and the side of the rivet head and between the surfaces of the metal and the set. Flush or flat sets are used for countersunk and flathead rivets. In order to seat flush rivets properly, be sure that flush sets are at least 1 inch in diameter.

8-26. Special draw sets are used to "draw up" the sheets in order to eliminate any opening between them before the rivet is bucked. Each draw set has a hole $\frac{1}{32}$ inch larger than the diameter of the rivet shank for which it is made. Occasionally, the draw set and rivet header are incorporated into one tool. The header part consists of a hole sufficiently shallow so that the set will expand the rivet and head it when struck with a hammer.

8-27. *Countersinks.* The countersink is a tool which cuts a cone-shaped depression around the rivet hole to allow the rivet to set flush with the surface of the skin. Countersinks are made with various angles to correspond to the various angles of the countersunk rivet heads. The angle of the standard countersink in figure 8 is 100°.

8-28. Special stop countersinks are available. Stop countersinks (see fig. 8) are adjustable to any desired depth and the cutters are interchangeable so that holes of various countersunk angles may be made. Some stop countersinks have a micrometer set arrangement, in increments of 0.001 inch, for adjusting the cutting depths.

8-29. *Dimpling dies.* The process of making an indentation or a dimple around a rivet hole so the top of the head of a countersunk rivet will be flush with the surface of the metal is called dimpling. Dimpling is accomplished with a male and female die, or forms, often called punch and die sets. The male die has a guide the size of the rivet hole and is beveled to correspond to the degree of countersink of the rivet head. The female die has a hole into which the male guide fits; it is beveled to a corresponding degree of countersink.

8-30. When dimpling, rest the female die on a solid surface, then place the material to be dimpled on the female die. Insert the male die in the hole to be dimpled and with a hammer strike the male die until the dimple is formed. Two or three solid hammer blows should be sufficient. A separate set of dies is necessary for each size of rivet and shape of rivet head.

8-31. An alternate method is to use a countersunk-head rivet instead of the regular male punch die and a draw set instead of the female die; then hammer the rivet until the dimple is formed.

8-32. Dimpling dies for light work can be used in portable pneumatic or hand squeezers. If the dies are used with a squeezer, they must, of course, be adjusted accurately to the thickness of the sheet being dimpled.

8-33. **Hole Preparation.** It is very important that the rivet hole be of the correct size and shape and free from burrs. If the hole is too small, the protective coating will be scratched from the rivet when the rivet is driven through the hole. If the hole is too large, the rivet will not fill it completely when the rivet is bucked, the joint will not develop

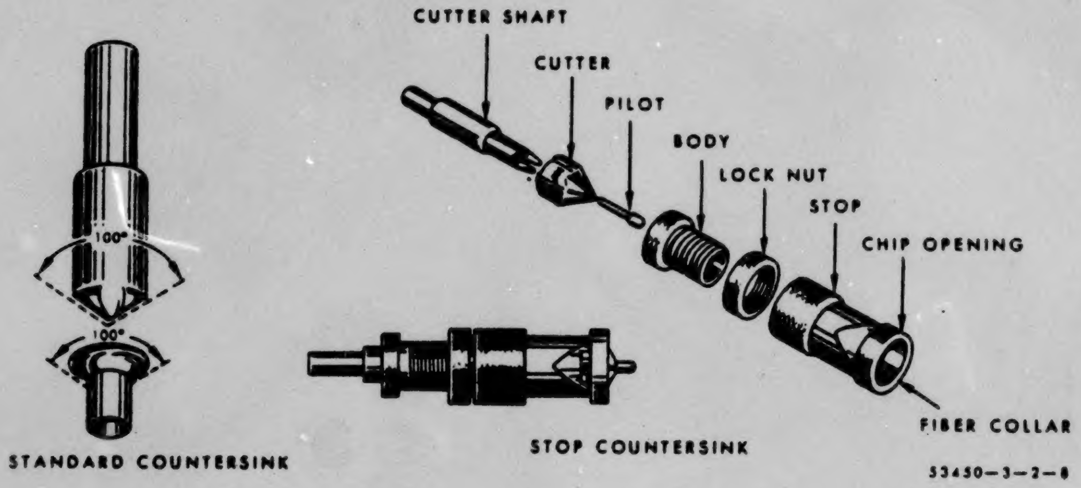


Figure 8. Countersinks.

TABLE 2
PILOT AND REAMING TWIST DRILL SIZES

Rivet Diameter	Pilot Size	Ream Size
3/32	3/32 (.0937)*	40 (.098)
1/8	1/8 (.125)	30 (.1285)
5/32	5/32 (.1562)	21 (.159)
3/16	3/16 (.1875)	11 (.191)
1/4	1/4 (.250)*	F (.257)
5/16	5/16 (.3125)	O (.316)
3/8	3/8 (.375	V (.377)

*Note that ream size exceeds the maximum tolerance of .004 inch. This is permissible only if the next larger drill size happens to be so much larger than the tolerance of .004 inch.

53430-3-2-12

full strength, and structural failure may occur at that spot.

8-34. If countersinking is required, consider the thickness of the metal and adopt the countersinking method recommended for that thickness. If dimpling is required, keep hammer blows, or dimpling pressures to a minimum so that no undue work-hardening occurs in the surrounding area.

8-35. *Drilling.* To make a rivet hole of the correct size, first drill a hole slightly undersize. This is known as predrilling and the hole is called a *pilot hole.* Ream the pilot hole with a twist drill of the correct size to get the required dimension. Pilot and reaming drill sizes are shown in table 2. The recommended clearance for rivet holes is .002- to .004-inch.

8-36. For hard metals, select a twist drill having an included angle of 118° and turn it at low speeds; but for soft metals, use a twist drill having an included angle of 90° and turn it at higher speeds. Thin sheets of aluminum alloys are drilled with greater accuracy by a drill having an included angle of 118° because the large angle of the drill has less tendency to tear or elongate the hole.

8-37. Center-punch locations for rivet holes before beginning the actual drilling. The center punch mark acts as a guide and lets the drill grip or bite into the metal with greater ease. Make the center punch mark large enough to prevent the drill from slipping out of position, but punch lightly enough so as not to dent the surrounding material. Hold a hard, smooth, wooden backing block securely in position behind the hole locations when drilling.

8-38. Drilling is usually done with a hand drill or with a light power drill. Hold the power drill firmly with both hands. Extend the index and middle fingers of the left hand against the metal to act as a guide in starting a hole, and as a snubber or brake when the drill goes through the material. Before beginning to drill, always test the inserted twist drill for trueness and vibration by spinning the hand drill or running the motor freely and watching the drill end. If the drill wobbles, the cause may be the burrs on its shank or that the drill is bent or incorrectly chucked. A drill that wobbles or is slightly bent must not be used as it causes enlarged holes.

8-39. Always hold the drill at right angles to the work, regardless of the position of the hole or the curvature of the material. Use an angle drill or drill extensions and adapters when access is difficult with a straight drill. Never tip the drill sideways when drilling or when withdrawing it from the material as this causes elongation of the hole.

8-40. When holes are drilled through sheet metal, small burrs are formed around the edge of the hole. This is especially true when you use a hand drill, since the drill speed is slow and there is a tendency to apply more pressure per drill revolution. Remove all burrs with a burr remover before riveting.

8-41. *Countersinking and dimpling.* An improperly made countersink reduces the strength of a flush-riveted joint and may cause failure of the

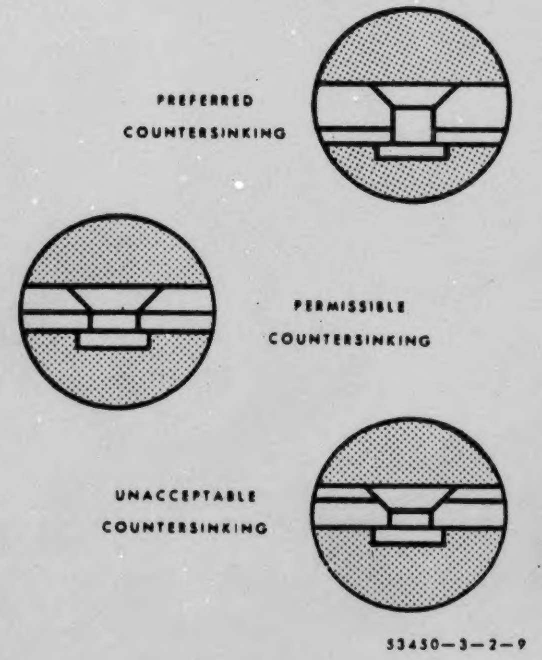


Figure 9. Countersinking.

sheet or the rivet head. The two methods of countersinking commonly used for flush riveting in aircraft construction and repair are: (1) machine or drill countersinking and (2) dimpling or press countersinking. The proper method for any particular application depends on the thickness of the parts to be riveted, the height and angle of the countersunk head, the tools available, and accessibility.

8-42. As a general rule, use the drill countersink method when the thickness of the material is greater than the thickness of the rivet head, and use the dimpling method on thinner material. Figure 9 illustrates general rules for countersinking. In the top example, note that the material is quite thick and that the head of the countersunk rivet extends only about halfway through the upper layer of metal. Countersinking will leave plenty of material for gripping; buckling of the material is out of the question.

8-43. In the middle example, the countersunk head reaches completely through the upper layer. This condition is permissible but is frowned upon.

8-44. In the bottom example, the head extends well into the second layer of material. This indicates that the material is thin and that most of it would be ground away by drill countersinking; therefore, dimpling is preferred. So, dimple if the material is thin. Dimpling will work best if the material is not over .040-inch thick.

8-45. Machine or drill countersinking is accomplished by a suitable cutting tool, machined to the desired angle, which cuts away the edge of the hole so that the countersunk head rivet fits snugly into the recess. The resulting recess is referred to as the "well" or "nest."

8-46. During the process of machine countersinking, first drill the original rivet hole to the exact rivet size as recommended in table 2. The limits within which the head of the rivet may extend either above or below the surface of the metal are close, 0.006-inch in most cases. Therefore, perform the countersinking accurately, using equipment which is capable of producing results within the specified tolerance.

8-47. Hold the countersinking tool firmly at right angles to the material. Do not tip it. Tipping elongates the well and prevents the countersunk rivet head from fitting properly. Oversized rivet holes, undersized countersink pilots (in the case of the stop countersink), chattering caused by improper use of the countersink or by a countersink in poor condition, and a countersink not running true in the chuck of the drill are some of the causes of elongated wells.

8-48. Press countersinking or dimpling can be accomplished by either of two methods. You may use male, and female die sets, or you may use the rivet as the male die and the draw die as the female die. In either case, the metal immediately surrounding the rivet hole is pressed to the proper shape to fit the rivet head. The depression thus formed, as in machine countersinking, is known as the "well" or "nest."

8-49. The rivet must fit the well snugly in order to obtain maximum strength. The number of sheets which can be dimpled simultaneously is limited by the capacity of the equipment used. The dimpling process may be accomplished by the use of hand tools, by dies placed in a pneumatic squeeze or single shot riveter, or by using a pneumatic riveting hammer.

8-50. Dimpling dies are made to correspond to any size and degree of countersunk rivet head available. The dies are usually numbered, and the correct combination of punch and die to use is indicated on charts specified by the manufacturer. Both male and female dies are machined accurately and have highly polished surfaces. The male die or punch is cone-shaped to conform to the rivet head and has a small concentric pilot shaft that fits into the rivet hole and female die. The female die has a corresponding degree of countersink into which the male guide fits.

8-51. When dimpling a hole, rest the female die on some solid surface, place the material on the female die, insert the male die in the hole to be dimpled, and then hammer the male die. Strike with several solid blows until the dimple is formed.

8-52. In some cases, the face of the male die is convex to allow for springback in the metal. Dies of this type are used to advantage when the sheet to be dimpled is curved. Some dies have flat faces and are principally used for flat work. Dimpling dies are usually made so that their included angle is 5° less than that of the rivet. This arrangement allows for springback of the metal.

8-53. In die dimpling, the pilot hole of the female die should be smaller than the diameter of the rivet to be used. Therefore, the rivet hole must be reamed to the exact diameter after the dimpling operation has been completed so that the rivet fits snugly.

8-54. When using a countersunk rivet as the male dimpling die, place the female die in the usual position and back it with a bucking bar. Place the rivet of the required type into the hole and strike the rivet with a pneumatic riveting hammer. This method of countersinking is often called *coin pressing*. It should be used only when the regular male die is broken or not available.

8-55. Coin pressing has a distinct disadvantage in that the rivet hole must be drilled to correct rivet size before the dimpling operation is accomplished. Since the metal stretches during the dimpling operation, the hole becomes enlarged and the

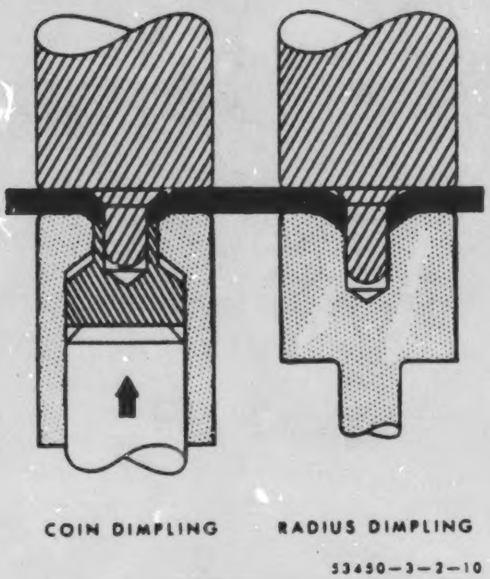


Figure 10. Radius and coin dimpling dies.

rivet must be swelled slightly before driving to produce a close fit. Because the rivet head will cause slight distortions in the recess and because these are characteristic only to that particular rivet head, it is wise to drive the same rivet that was used as the male die during the dimpling process. Do not substitute another rivet, either of the same size or a size larger.

8-56. *Thermo dimpling.* This type of dimpling has only recently been developed into an efficient method. It consists of two processes: radius dimpling and coin dimpling. The major difference between radius and coin dimpling is in the construction of the female die. In radius dimpling, use a solid female die. For coin dimpling, use a sliding ram female die, as illustrated in figure 10. It is this sliding coining ram that makes the coin dimpling process superior.

8-57. During the coin dimpling process, the metal is coined (made to flow) into the contours of the dies so that the dimple assumes the true shape of the die. The pressure exerted by the coining ram prevents the metal from compressing and thereby assures uniform cross-sectional thickness of the sides of the dimple and a true conical shape.

8-58. Coin dimpling offers several advantages. It improves the configuration of the dimple, produces a more satisfactory aerodynamic skin surface, eliminates radial and circumferential cracking, insures a stronger and safer joint, and allows identical dies to be used for both skin and understructure dimpling.

8-59. The material being used is a very important factor to consider in any dimpling operation. Materials such as corrosion-resistant steel, magnesium, and titanium each present different dimpling problems.

8-60. The 2024T aluminum alloy can be satisfactorily coin dimpled either hot or cold. However, cracking in the vicinity of the dimple may result from cold dimpling because of hard spots in the metal. Hot dimpling will prevent such cracking.

8-61. The 7075–T6 and 2024–T81 aluminum alloys are always hot dimpled. Magnesium alloys also must be hot dimpled because, like 7075–T6, they have low formability qualities. Titanium is another metal that must be hot dimpled, because it is tough and resists forming. The same temperature and dwell time used to hot dimple 7075–T6 is used for titanium.

8-62. Corrosion-resistant steel is cold dimpled because the temperature range of the heating unit is not high enough to affect dimpling.

8-63. The coin ram dimpling dies are designed with a number of built-in features. The faces of both the male and female dies are dished (the male concave and the female convex) at an angle of 2° on the pilot. This facilitates removal of the metal after the dimple has been made.

8-64. The female dimpling set has two parts: the body, which is merely a counterpart of the male die; and the coining ram, which extends up through the center of the conical recess of the body. In forming a dimple, force the metal down into the female die by the male die. The metal first contacts the coining ram, and this supports the metal as it is forced down into the conical recess. When the two dies close to the point where the forces of both are squeezing the material, the coining ram forces the metal back into the sharp corners of the dies.

8-65. When cold dimpling, use the dies alone. When hot dimpling, slip a strap or block heater over either or both dies and connect them to an electric current.

8-66. The dies should be kept clean at all times and in good working order. It is advisable to clean them regularly with steel wool. Special precautions must be taken when the dies are in the machine. If the machine is operated with the dies in place but without material between them, the male die will enlarge and ruin the coining ram.

8-67. There are two types of thermo dimpling equipment: stationary and portable. The most commonly used are the CP 450 EA stationary dimpler with control panel attached, the CP 351 portable squeezer, and the ZT 1804 bucking bar.

8-68. Portable dimplers are usually controlled by the ZT 1809C portable control panel. Control panels are used for all thermo dimpling. They insure fully automatic cycling, heating, and timing control at all times.

8-69. The CP 450 EA stationary dimpler is used to dimple large pieces of either ferrous or nonferrous aircraft metal up to ⅛-inch thick. The squeezing action is pneumatically controlled, while the dwell time is electrically controlled. The dimpling cycle is operated by a foot switch so that both hands of the operator are free to hold the work being dimpled.

8-70. When possible, coin dimpling should be performed on stationary equipment and before the assembly of parts. However, many instances arise in which dimpling must be done after parts are assembled to other structures. In such cases, dimpling operations are performed on portable squeeze dimplers. Most squeezers may be used for cold dimpling or combined with a junction box for hot dimpling.

8-71. There are dimpling applications in which it is not possible to accommodate any squeezer or yoke type equipment. Under these circumstances, it is necessary to use a pneumatic hammer and a bucking bar type of tool to hold the dimpling dies.

8-72. When the ZT 1804 bucking bar is used with either one or two heated dies, a ZT control panel is required. The pneumatic hammer plugs into the high-pressure outlet and the bucking bar into the low-pressure outlet. The bucking bar carries a female die and controls the dimpling cycle by an electrical switch closed by the operator when the tools are positioned on the work.

8-73. **Driving Rivets.** All types of solid rivets are driven in basically the same manner. The chief difference is in the sizes and weights of the guns and bucking bars used to drive the rivets. The methods of driving solid shank rivets are classified as one of two types, depending on whether the riveting equipment is portable or stationary. Since stationary riveting equipment is seldom used in airframe repair work, only portable equipment used in hand, pneumatic, and squeeze riveting methods is discussed here.

8-74. Before driving any rivets, be sure all holes line up perfectly, all shavings and burrs have been removed, and the parts to be riveted are fastened securely together.

8-75. Two men, a "gunner" and a "bucker," usually work as a team when installing rivets. However, on some jobs the riveter holds a bucking bar with one hand and operates a riveting gun with the other. When a team is riveting, an efficient signal system can be used to develop the necessary teamwork. The code usually consists of tapping the bucking bar against the work; one tap may mean "not fully seated, hit it again"; two taps may mean "good rivet"; three taps may mean "bad rivet, remove and drive another"; and so on.

8-76. *Bucking.* Selection of the appropriate bucking bar is one of the most important factors in bucking rivets. If the bar does not have the correct shape, it will deform the rivet head; if the bar is too light, it will not give the necessary bucking weight, and the material may become bulged toward the shop head; and, if the bar is too heavy, weight and the bucking force may cause the material to bulge away from the shop head. Weights of bucking bars range from a few ounces to 10 pounds, depending upon the nature of the work. Recommended weights of bucking bars to be used with various rivet sizes are given in table 3.

TABLE 3
RECOMMENDED BUCKING BAR WEIGHTS

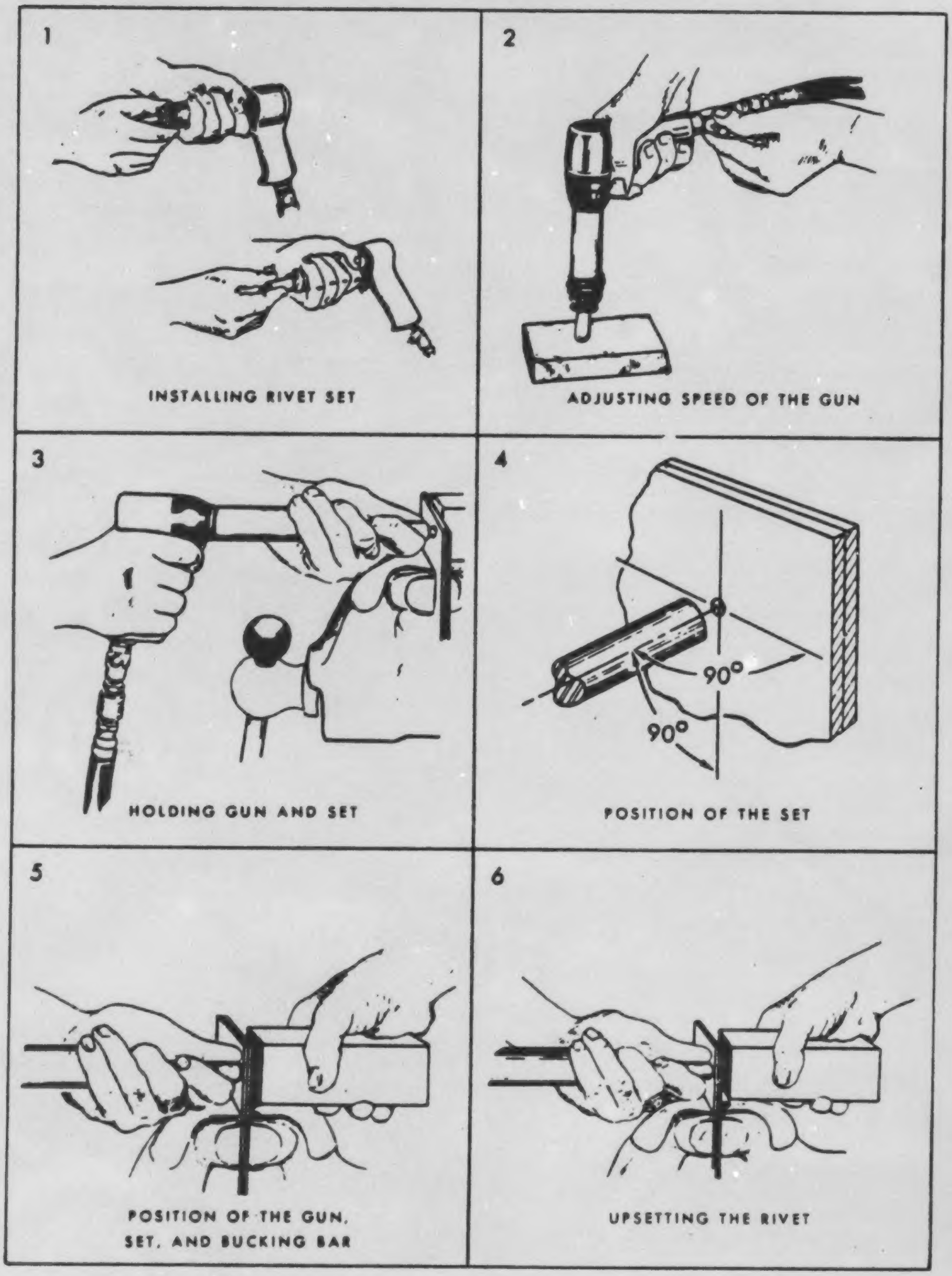
RIVET DIAMETER (IN INCHES)	APPROX. WEIGHT (IN POUNDS)
3/32	2 to 3
1/8	3 to 4
5/32	3 to 4 1/2
3/16	4 to 5
1/4	5 to 6 1/2

53450-3-2-13

8-77. Always hold the face of the bucking bar at right angles to the rivet shank. Failure to do this will cause the rivet shank to bend with the first blows of the rivet gun, and the material will become marred with the final blows. The bucker must hold the bucking bar in place until the rivet is completely driven. If the bucking bar is removed while the gun is in operation, the rivet set may be driven through the material. Do not bear down too heavily on the shank of the rivet. Allow the weight of the bucking bar to do most of the work while your hands merely guide the bar and supply the necessary tension and rebound action.

8-78. Allow the bucking bar to vibrate in unison with the gun set. This process is called coordinated bucking. Coordinated bucking can be developed through pressure and stiffness applied at the wrists; with experience, a high degree of deftness can be obtained. Should you fail to vibrate the bar at gun-set speed, you will cause the material to kink into a depression.

8-79. Lack of proper vibrating action, the use of a bucking bar that is too light or too heavy, and failure to hold the bucking bar at right angles to the rivet can all cause defective rivet heads. A rivet going "clubhead" (malforming) can be corrected by rapidly moving the bucking bar across the rivet head in a direction opposite to the direction of clubhead travel. This corrective action can be accomplished only while the gun is in action


1
INSTALLING RIVET SET
2
ADJUSTING SPEED OF THE GUN
3
HOLDING GUN AND SET
4
90°
90°
POSITION OF THE SET
5
POSITION OF THE GUN, SET, AND BUCKING BAR
6
UPSETTING THE RIVET

53450—3—2—11

Figure 11. Riveting procedures.

and the rivet is partly driven. If a rivet shank bends at the beginning of the bucking operation, place the bar in the corrective position only long enough to straighten the shank.

8-80. *Hand driving*. Under certain conditions, you may have to do all your aircraft riveting by hand driving. You can use either of two methods of hand riveting, depending upon the location and accessibility of the work. In one method, you drive from the manufactured head end of the rivet with a hand set and hammer and buck the shank end with a suitable bucking bar. In the other method, you drive from the shank end of the rivet with a hand set and a hammer and buck the manufactured head with a hand set held in a vise or a bottle bar (a special bucking bar recessed to hold a rivet set). This method is known as reverse riveting. It is commonly used in hand riveting but is not considered good practice in pneumatic riveting.

8-81. When using either of the described methods, keep hammer strokes to a minimum. Too much hammering will change the crystaline structure of the rivet or the material around it, causing the joint to lose some of its strength. Hold the bucking bar and rivet set square with the rivet at all times. Misuse of the rivet set and bucking bar will result in marring or scratching the rivet head or material, and may cause undue corrosion. This, in turn, will weaken the structure of the aircraft.

8-82. The diameter of a correctly formed shop head should be 1½ diameters of the rivet shank and the height should be about ½ diameter.

8-83. *Pneumatic driving*. The procedure for pneumatic riveting is practically the same as for hand riveting. Preparation of the sheet, selection of rivets, and drilling of rivet holes are the same. In hand riveting, however, you apply the pressure for bucking the rivet by using a hand set and hammer. In pneumatic riveting, you apply the pressure with a set and an air-driven hammer or gun.

8-84. To get good riveting results with a pneumatic rivet gun, follow these basic pointers:

a. Select the right type and size of rivet gun and the correct rivet set for the size of rivet to be driven.

b. Install the rivet set firmly, as shown in example 1 of figure 11.

c. Adjust the speed of gun (vibrations per minute, vpm) as shown in example 2 of figure 11.

CAUTION: Always press set firmly against a block of wood before pressing the trigger. Never operate the gun without resistance against the set as the vibrating action may cause the retaining spring to break, allowing the gun set to fly out of the gun. Also, free vibration may flare or mushroom the gun end of the set, causing it to bind in the barrel of the gun.

d. When operating the rivet gun, hold the gun with one hand and the rivet set with the other. (See example 3, fig. 11)

e. Hold the rivet set at right angles to work to prevent damage to the rivet head or the surrounding material (example 4 of fig. 11).

f. Hold the gun and set tightly against the rivet head and do not remove them until you have removed your finger from the trigger (example 5 of fig. 11).

g. Upset the rivet with one medium blast (example 6 of fig. 11).

h. Remove the bucking bar and check the shop head of the rivet. It should be 1½ times the diameter of the rivet in width and ½ times the rivet diameter in height.

i. If the rivet needs further driving, repeat the necessary procedures to complete the job.

8-85. A small piece of adhesive tape applied to the cupped end of the rivet set often corrects an unsatisfactory cupped condition, which occasionally gives trouble in forming uniformly shaped rivet heads.

8-86. *Squeeze riveting*. The squeezer method of driving a rivet produces the most uniform and balanced type of shop head. Each rivet is upset in a single operation, all rivets are headed over with uniform pressure, all heads are formed alike, and each rivet shank is sufficiently and uniformly expanded to completely fill each rivet hole. Squeeze riveters come equipped with pairs of end sets, each pair being designed for a particular job. Once you have selected the correct end set and adjusted the squeezer for a particular application, all rivets will be driven uniformly, thus providing an efficient method of riveting.

8-87. Portable squeezers are particularly suited for riveting large assemblies where the tool must be moved in relation to the work. They are not too heavy and can easily be operated by one person. The preparation of the material for riveting with the squeeze riveter is the same as for hand or pneumatic riveting. For better results when using the squeeze riveter, observe these rules:

a. Carefully select and insert suitable end sets to match the rivet being used. The importance of using the right end sets cannot be overemphasized. It is impossible to buck the rivet properly unless the correct pairs are used. Always be sure that the air is shut off or the squeezer is disconnected when inserting end sets.

b. Adjust the squeezer cylinder pressure so that you obtain the correct pressure for the diameter of the rivet being used. Most squeezers are equipped

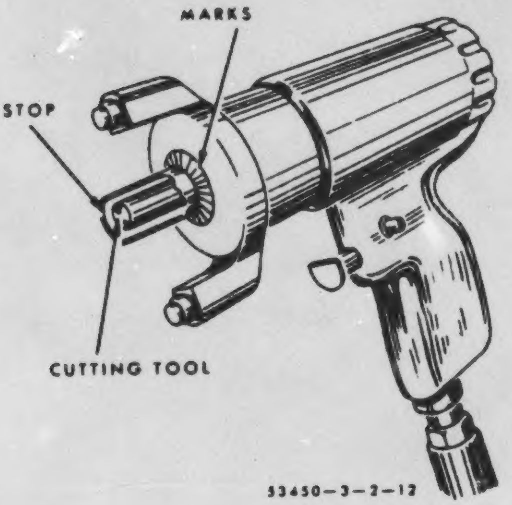


Figure 12. Microshaver.

with a blow-off valve to regulate the cylinder pressure. This unit governs the amount of air pressure allowed in the cylinder.

c. Carefully regulate the gap to conform to the length of the rivet being used. Some squeezers are equipped with a gap regulator which controls the stroke of the plunger of a C yoke squeezer, or the movement of the movable jaw of an alligator yoke squeezer. For squeezers not equipped with a gap regulator, the gap can be adjusted by placing metal shims under the end sets of both jaws, or by using end sets of different lengths. On some types of squeeze riveters, the end set on the stationary jaw is held in place by an Allen screw, which can be adjusted to regulate the gap.

d. Before using the squeezer on the work, test the cylinder pressure and gap for accuracy of adjustment on a piece of scrap material. The scrap material must be the same thickness as the material being used, and the rivets the same length and diameter.

e. If the parts to be riveted are small and easily handled, mount the squeeze riveter in a bench vise or in a special clamp, and hold the part to be riveted in your hand.

8-88. **Microshaving.** Sometimes it is necessary to use a microshaver when making a repair involving the use of countersunk rivets. If the smoothness of the material (such as skin) requires that all countersunk rivets be driven within a specific tolerance, a microshaver is used. This tool has a cutter, a stop, and two legs or stabilizers (see fig. 12).

8-89. The cutting portion of the microshaver is located inside the stop. The depth of cut can be adjusted by pulling outward on the stop and turning it in either direction (clockwise for deeper cuts). The marks on the stop permit adjustments of .001-inch.

8-90. If the microshaver is adjusted and held correctly, it will cut the head of a countersunk rivet to within .002-inch without damaging the surrounding material. Adjustments should always be made on scrap material. When correctly adjusted, the shaver will leave a small round dot about the size of a pinhead on the microshaved rivet.

8-91. **Rivet Failures.** Generally speaking, the design of riveted joints is based on the theory that the total joint strength is simply the sum of the individual strengths of a whole group of rivets. It is then obvious that, if any one rivet fails, its load must immediately be carried by others of the group; if they are unable to carry this added load, progressive joint failure then occurs. Stress concentrations will usually cause one rivet to fail first; and careful analysis of such a rivet in a joint will indicate that it has been too highly loaded, the possibility being that neighboring rivets may have partially failed.

8-92. *Shear failure.* Shear failure is perhaps the most common of rivet failures. It is simply a breakdown of the rivet shank by forces acting along the plane of two adjacent sheets, causing a slipping action which may be severe enough to cut the rivet shank in two. If the shank becomes loaded beyond the yield point of the material and remains overloaded, a permanent shift is established in the sheets and the rivet shank may become joggled.

8-93. *Bearing failure.* If the rivet is excessively strong in shear, bearing failure occurs in the sheet at the edge of the rivet hole. The application of large rivets in thin sheets brings about such a failure. In that case, the sheet is locally crushed or buckled, and the buckling destroys the rigidity of the joint. Vibrations, set up by engine operation or by air currents in flight, may cause the buckled portion to flutter and the material to break off close to the rivet head. If buckling occurs at the end of the sheet, a tearout may result. In either case, replacement of the sheet is necessary.

8-94. *Head failure.* Head failure may result from complex loadings occurring at a joint, causing stresses of tension to be applied to the rivet head. The head may fail by shearing through the area corresponding to the rivet shank or, in thicker sheets, may fail through a prying action which causes failure of the head itself. Any visible head distortion is cause for replacement. This latter type of head failure is especially common in blind rivets.

8-95. **Rivet Inspection.** In order to obtain high structural efficiency in the manufacture and repair

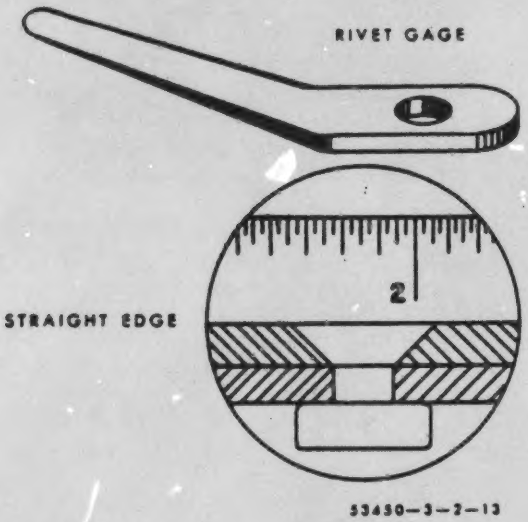


Figure 13. Tools used to gage rivets.

of aircraft, an inspection must be made of all rivets before the part is put in service. This inspection consists of examining both the shop and manufactured heads and the surrounding skin and structural parts for deformities. A scale or rivet gage can be used to check the condition of the upset rivet head to see that it conforms to the proper requirements. Deformities in the manufactured head may be detected by the trained eye alone. However, on flush rivets, you may use a straightedge, as shown in figure 13.

8-96. Some common causes of unsatisfactory riveting are improper bucking, rivet set slipping off or being held at the wrong angle, and rivet holes or rivets of the wrong size. Countersunk rivets not flush with the well, work not properly fastened together during riveting, the presence of burrs, rivets too hard, too much or too little driving, and rivets out of line are also causes.

8-97. Occasionally, during the repair of an aircraft structural part, it is wise to examine adjacent parts to determine the true condition of neighboring rivets. In doing so, you may have to remove the paint. The presence of chipped or cracked paint around the heads may indicate shifted or loose rivets. Look for tipped or loose rivet heads. If the heads are tipped or if rivets are loose, they will show up in groups of several consecutive rivets and will probably be tipped in the same direction. If heads which appear to be tipped are not in groups and are not tipped in the same direction, tipping may have occurred during some previous installation.

8-98. Inspect rivets which you know have been critically loaded but which show no visible distortion by drilling off the head and carefully punching out the shank. Upon examination, if the shank appears joggled and the holes in the sheet misaligned, the rivet has failed in shear. In that case, try to determine what is causing the shearing stress and take the necessary corrective action. Flush rivets that show head slippage within the countersink or dimple, indicating either sheet bearing failure or rivet shear failure, must be removed for inspection and probable replacement.

8-99. Joggles in removed rivet shanks indicate partial shear failure. Replace these rivets with the next larger size. Also, if the rivet holes show elongation, replace the rivets with the next larger size. Sheet failures (such as tearouts, cracks between rivets, and the like) usually indicate damaged rivets, and the complete repair of the joint may require replacement of the rivets with the next larger size.

8-100. The general practice of replacing a rivet with the next larger size ($\frac{1}{32}$ inch greater diameter) is necessary to obtain the proper joint strength of rivet and sheet when the original rivet hole is enlarged. If the rivet in an elongated hole is replaced by a rivet of the same size, its ability to carry its share of the shear load is impaired and joint weakness results.

8-101. **Removing Rivets.** When removing a rivet for replacement, be very careful so that the rivet hole will retain its original size and shape and replacement with a larger size rivet will not be necessary. If the rivet is not removed properly, the strength of the joint may be weakened and the replacement of rivets made more difficult.

8-102. When removing a rivet, work on the manufactured head. It is more symmetrical about the shank than the shop head, and there will be less chance of damaging the rivet hole or the material around it. To remove rivets use hand tools, a power drill, or a combination of both. The preferred method is to drill through the rivet head and drive out the remainder of the rivet with a drift punch. First, file a flat area on the head of any round- or brazier-head rivet, and center punch the flat surface for drilling. On thin metal, back up the rivet on the upset head when center punching to avoid depressing the metal. The dimple in 2117T rivets usually eliminates the necessity of filing and center punching the rivet head.

8-103. Select a drill one size smaller than the rivet shank and drill out the rivet head. When using a power drill, set the drill on the rivet and rotate the chunk several revolutions by hand before turning on the power. This procedure helps the drill cut a good starting spot and eliminates the chance of the drill slipping off and tracking across the metal. Drill the rivet to the depth of its head, while holding the drill at a 90° angle. Be careful not to drill too deep, as the rivet shank will turn

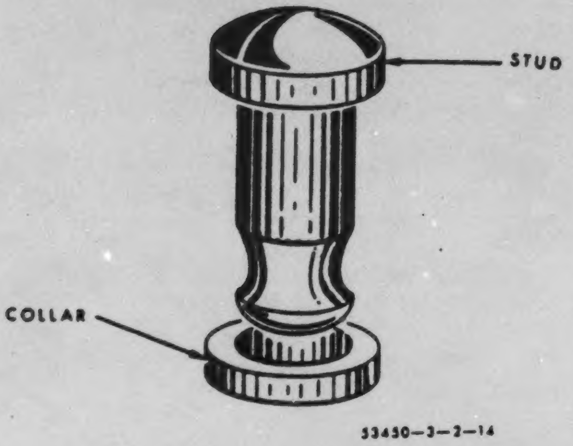

STUD
COLLAR
53450—3—2—14

Figure 14. Hi-Shear (pin) rivet.

with the drill and cause a tear. The rivet head will often break away and climb the drill, which is a good signal to withdraw the drill. If the rivet head does not come loose of its own accord, insert a drift punch into the hole and twist slightly to either side until the head comes off.

8-104. Drive out the shank of the rivet with a drift punch slightly smaller than the diameter of the shank. On thin metal or unsupported structures, support the sheet with a bucking bar while driving out the shank. If the shank is exceptionally tight after the rivet head is removed, drill the rivet about two-thirds of the way through the thickness of the material and then drive out the remainder of the rivet with a drift punch.

8-105. The procedure for the removal of flush rivets is the same as that just described except that no filing is necessary. Be very careful to avoid elongation of the dimpled or the countersunk holes. The rivet head should be drilled to approximately one-half the thickness of the top sheet.

9. Hi-Shear Rivets

9-1. Hi-Shear (trade name) pin rivets are classified as special rivets but are not of the blind type. Access to both sides of the material is required to install this type of rivet. Hi-Shear rivets have the same shear strength as bolts of equal diameters: about 40 percent of the weight of a bolt. They require only about one-fifth as much time for installation as a bolt, nut, and washer combination. They are approximately three times as strong as solid shank rivets.

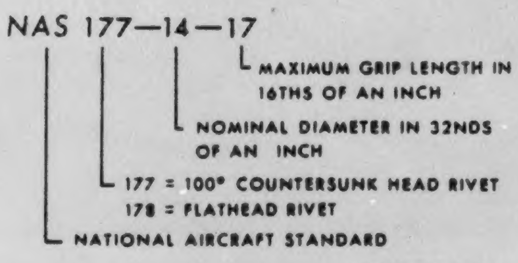

NAS 177—14—17
MAXIMUM GRIP LENGTH IN 16THS OF AN INCH
NOMINAL DIAMETER IN 32NDS OF AN INCH
177 = 100° COUNTERSUNK HEAD RIVET
178 = FLATHEAD RIVET
NATIONAL AIRCRAFT STANDARD
53450—3—2—15

Figure 15. Breakdown of a pin rivet number.

9-2. Pin rivets are essentially threadless bolts. The pin is headed at one end and is grooved about the circumference at the other. A metal collar is swaged onto the grooved end, effecting a firm, tight fit, as illustrated in figure 14.

9-3. Pin rivets are fabricated in a variety of materials and are used only in shear applications. They are never used where the grip length is less than the shank diameter.

9-4. **Selection.** The proper length rivet is determined by trial or by part number. To determine correct grip length by trial, insert the correct diameter rivet in the hole. The straight portion of the shank must extend more than $\frac{1}{16}$ inch through the material. Place a collar over the grooved end of the rivet. Check the position of the collar.

NOTE: The collar is positioned so that the shearing edge of the pin groove is just below the top of the collar it is permissible to add an approximately 0.032-inch steel washer between the collar and the material to bring the collar to the desired

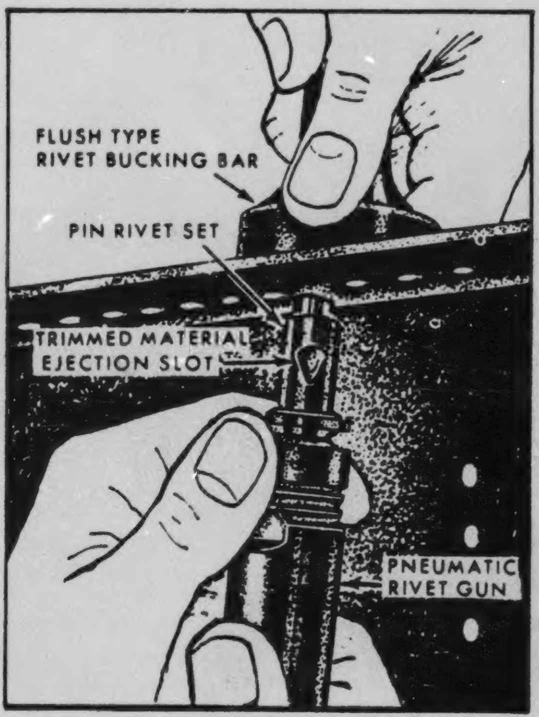

FLUSH TYPE RIVET BUCKING BAR
PIN RIVET SET
TRIMMED MATERIAL EJECTION SLOT
PNEUMATIC RIVET GUN
53450-3-2-16

Figure 16. Driving pin rivets from collar end.

location. The washer may be positioned on the rivet head side of the material when a flathead rivet is used.

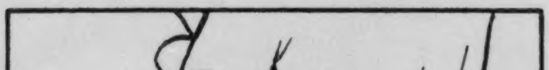
9-5. Part numbers for pin rivets give you the diameter and grip length of the individual rivets. A typical part number breakdown is illustrated in figure 15.

9-6. **Installation Tools.** Hi-Shear rivets are installed with standard bucking bars and pneumatic riveting hammers. They require the use of a special gun set that incorporates collar swaging and trimming and a discharge port through which excess collar material is ejected. A separate size set is required for each shank diameter.

9-7. **Installation Procedures.** Prepare holes for pin rivets with the same care as for other close-tolerance rivets or bolts. At times, it is necessary to spot-face the area under the head of the pin so that the head of the rivet can fit tight against the material. The spot-faced area should be 1/16 inch larger in diameter than the head diameter.

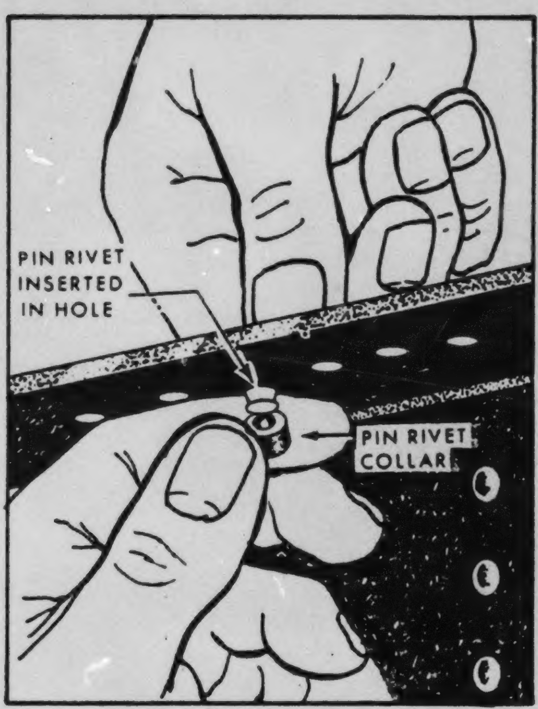
9-8. Pin rivets are driven from either end, as illustrated in figures 16 and 17. Procedures to be used in driving a pin rivet from the collar end are:

a. Insert the rivet in the hole, as illustrated in figure 18.



53450-3-2-17

Figure 17. Driving pin rivets from head end.


PIN RIVET INSERTED IN HOLE
PIN RIVET COLLAR

53450-3-2-18

Figure 18. Inserting pin rivet.

b. Place a bucking bar against the rivet head.

c. Slip the collar over the protruding rivet end.

d. Place previously selected rivet set and gun over the collar. Align the gun so that it is perpendicular to the material.

e. Depress the trigger on the gun, applying pressure to the rivet collar. This action will cause the rivet collar to swage into the groove on the rivet end.

f. Continue the driving action until the collar is properly formed and excess collar material is trimmed off, as illustrated in figure 19.

9-9. Procedures to be used in driving a pin rivet from the head end are:

a. Insert the rivet in the hole.

b. Slip the collar over the protruding end of rivet.

c. Insert the correct size gun rivet set in a bucking bar and place the set against the collar of the rivet.

d. Apply pressure against the rivet head with a flush rivet set and pneumatic riveting hammer.

e. Continue applying pressure until the collar is formed in the groove and excess collar material is trimmed off.

9-10. **Inspection.** Pin rivets are inspected on both sides of the material. The head of the rivet must not be marred and must fit tightly against the material. Figure 20 illustrates acceptable and unacceptable rivets.

9-11. **Removal of Pin Rivets.** The conventional method of removing rivets by drilling off the head may be used on either end of the pin rivet, as drawn in figure 21. Center punching is recommended prior to the application of drilling pressure. In some cases, the alternate methods listed below are more desirable:

a. Grind a chisel edge on a small pin punch to a blade width of ⅛ inch. Place this tool at right angles to the collar and drive with a hammer to split collar down one side. Repeat operation on opposite side. Then, with chisel blade, pry collar from rivet. Tap rivet out of hole.

b. Use a special hollow punch having one or more blades placed so as to split the collar. Pry collar from groove and tap out rivet.

c. Grind a pair of nippers so that cutting blades will cut collar in two pieces, or use nippers at right angles to rivet and cut through small neck.

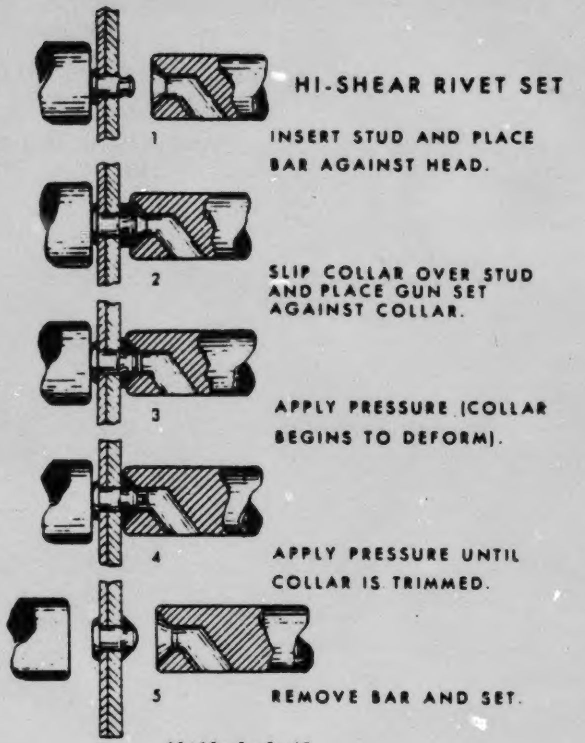
d. A hollow-mill collar cutter can be used in a power hand drill to cut away enough collar material to permit rivet to be tapped out of the work.

10. Mechanical Expansion Rivets

10-1. There are many places on the aircraft where access to both sides of the riveted structure or structural part is impossible. There are many places where the space is so limited that a bucking bar cannot be used. Also in the attachment of many nonstructural parts, such as aircraft interior furnishings, flooring, and the like, the full strength of solid shank rivets is not necessary. For use in such places, special rivets have been designed which can be bucked from the front.

10-2. These special rivets are sometimes lighter than solid-shank rivets, but they are strong enough for the intended use. These rivets are manufactured by several corporations and have characteristics that require special installation tools, special installation procedures, and special removal procedures. Since these rivets are usually inserted in places where one head (generally the shop head) cannot be seen, they are often called blind rivets. There are three types of mechanically expanded rivets: (1) self-plugging (friction lock) rivets, (2) self-plugging (mechanical lock) rivets, and (3) pull-thru rivets.

10-3. **Self-Plugging (Friction Lock) Rivets.** Although the self-plugging (friction lock) blind rivets are manufactured by several companies, the same general basic information about their fabrication, composition, use, selection, installation procedures, inspection, and removal procedures applies to all of them.


HI-SHEAR RIVET SET
1
INSERT STUD AND PLACE BAR AGAINST HEAD.
2
SLIP COLLAR OVER STUD AND PLACE GUN SET AGAINST COLLAR.
3
APPLY PRESSURE (COLLAR BEGINS TO DEFORM).
4
APPLY PRESSURE UNTIL COLLAR IS TRIMMED.
5
REMOVE BAR AND SET.

53450—3—2—19

Figure 19. Using pin rivet set.

10-4. *Fabrication.* Self-plugging (friction lock) rivets are manufactured in two parts: (1) a rivet head with a hollow shank or sleeve, and (2) a stem that extends through the hollow shank. Figure 22 is a line drawing of a protruding head and a countersunk head self-plugging rivet manufactured by one company.

10-5. Several operations, in their proper sequence, happen when a pulling force is applied to the stem of the rivet: (1) the stem is pulled into the rivet shank, (2) the mandrel portion of the stem forces the rivet shank to expand, and (3) the friction (or pulling action pressure) becomes great enough to cause the stem to snap at a break-off groove on the stem. The plug portion (bottom end of the stem) is retained in the shank of the rivet. The plug in the rivet gives the rivet a greater shear strength than could be derived from a hollow rivet.

10-6. Self-plugging (friction lock) rivets are fabricated in two common head styles: a protruding head similar to the AN470 or universal head, and a 100° countersunk head. Other head styles are available from some manufacturers.

10-7. The stem of the self-plugging (friction lock) rivet may have a knot or knob on the upper portion or it may have a serrated portion, as shown in figure 22. The type of stem is determined by the stock number and specifications met by the manufacturers.

10-8. *Composition.* Self-plugging (friction lock) rivets are fabricated from several materials. Rivets are available in the following material combinations: stem 2017 aluminum alloy and sleeve 2117 aluminum alloy; stem 2017 aluminum alloy and sleeve 5056 aluminum alloy; and stem steel and sleeve steel.

10-9. *Use.* Self-plugging (friction lock) rivets are designed so that installation requires only one person; it is not necessary to have the work accessible from both sides; and pulling strength of the rivet stem is such that a uniform job can always be assured. Because it is not necessary to have access to the opposite side of the work, self-plugging (friction lock) rivets can be used to attach assemblies to hollow tubes, corrugated sheet, hollow boxes, etc. Because a hammering force is not necessary to install the rivet, it can be used to attach assemblies to plywood or plastics.

10-10. *Selection.* Factors to consider in the selection of the correct rivet for installation are: installation location, composition of the material

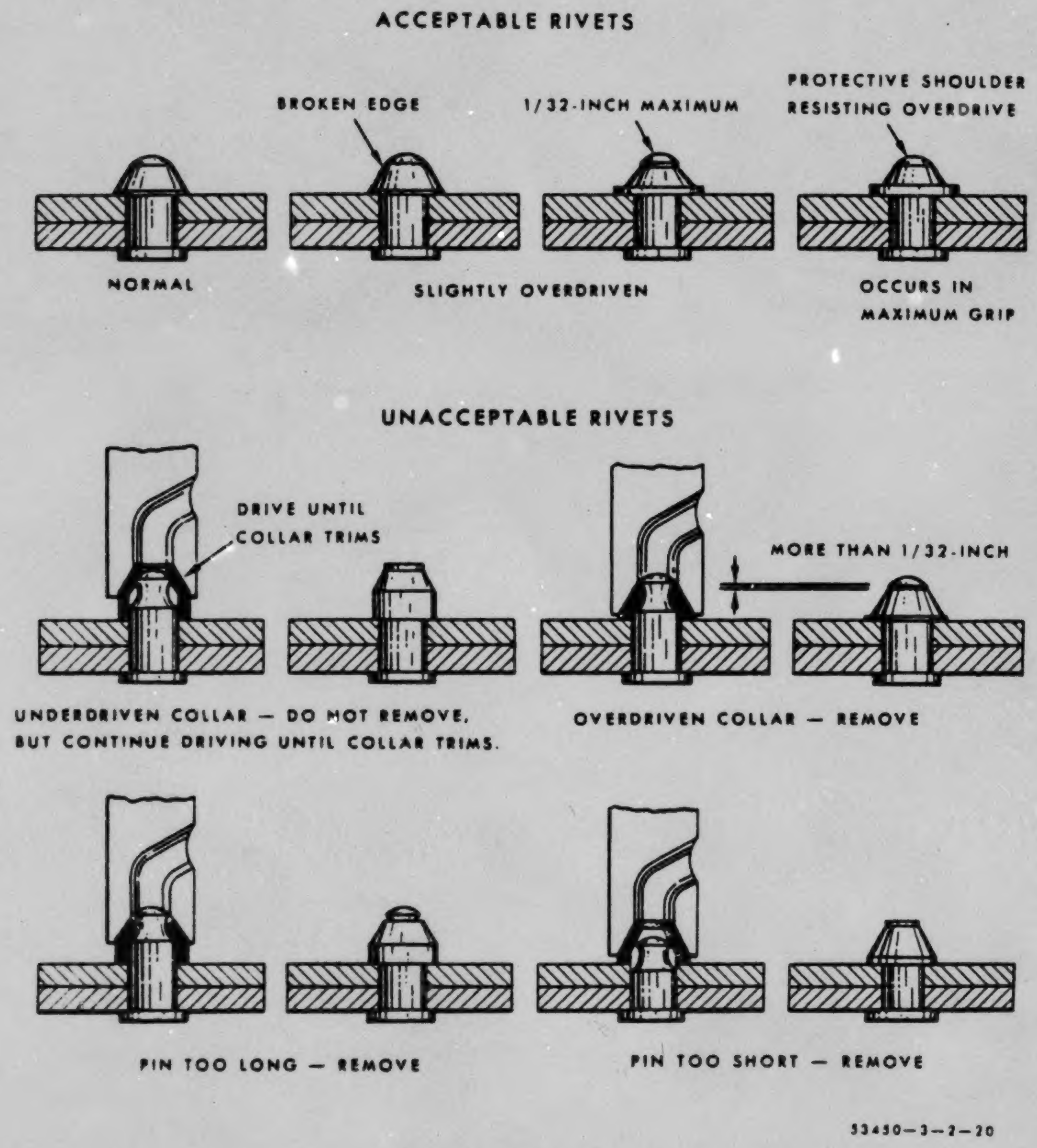

ACCEPTABLE RIVETS
BROKEN EDGE
1/32-INCH MAXIMUM
PROTECTIVE SHOULDER RESISTING OVERDRIVE
NORMAL
SLIGHTLY OVERDRIVEN
OCCURS IN MAXIMUM GRIP
UNACCEPTABLE RIVETS
DRIVE UNTIL COLLAR TRIMS
MORE THAN 1/32-INCH
UNDERDRIVEN COLLAR — DO NOT REMOVE, BUT CONTINUE DRIVING UNTIL COLLAR TRIMS.
OVERDRIVEN COLLAR — REMOVE
PIN TOO LONG — REMOVE
PIN TOO SHORT — REMOVE
53450-3-2-20

Figure 20. Pin rivet inspection.

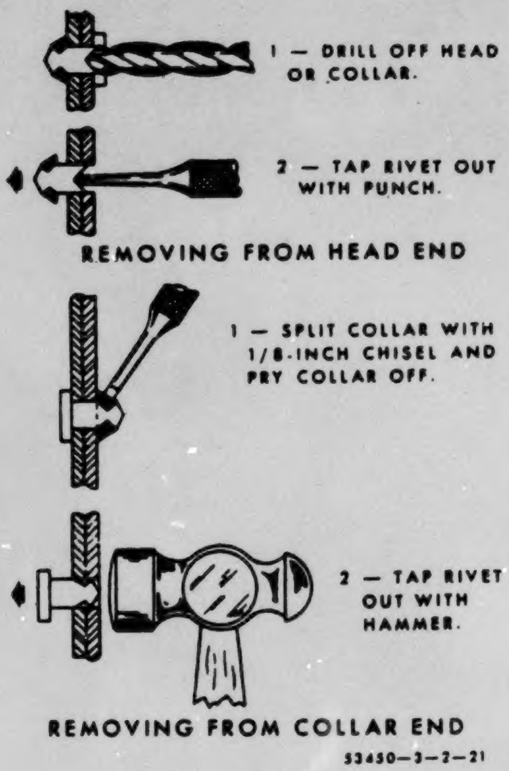

1 — DRILL OFF HEAD OR COLLAR.
2 — TAP RIVET OUT WITH PUNCH.
REMOVING FROM HEAD END
1 — SPLIT COLLAR WITH 1/8-INCH CHISEL AND PRY COLLAR OFF.
2 — TAP RIVET OUT WITH HAMMER.
REMOVING FROM COLLAR END
53450—3—2—21

Figure 21. Removal of pin rivets.

being riveted, thickness of the material being riveted, and strength desired.

10-11. If the rivet is to be installed on an aerodynamically smooth surface, or clearance for an assembly is needed, countersunk-head rivets should be selected. In other areas where clearance or smoothness is not a factor, the protruding head type rivet may be used.

10-12. Material composition of the rivet shank will depend upon the type of material being riveted. Aluminum alloy 2117 shank rivets can be used on most aluminum alloys. Aluminum alloy 5056 shank rivets are used when the material being riveted is magnesium. Steel rivets are always selected for riveting assemblies fabricated from steel.

10-13. The thickness of the material being riveted determines the overall length of the shank of the rivet. As a rule, the shank of the rivet extends beyond the material thickness approximately $\frac{3}{64}$ inch to $\frac{1}{8}$ inch before the stem is pulled, as drawn in figure 23.

10-14. Each company that manufactures self-plugging (friction lock) rivets has a code number to help users obtain the correct rivet for the grip range or material thickness of a particular installation. In addition, the Air Force also has military standard (MS) numbers for identification purposes. The examples of part numbers for self-plugging (friction lock) rivets, illustrated in figure 24, are only a sample of each.

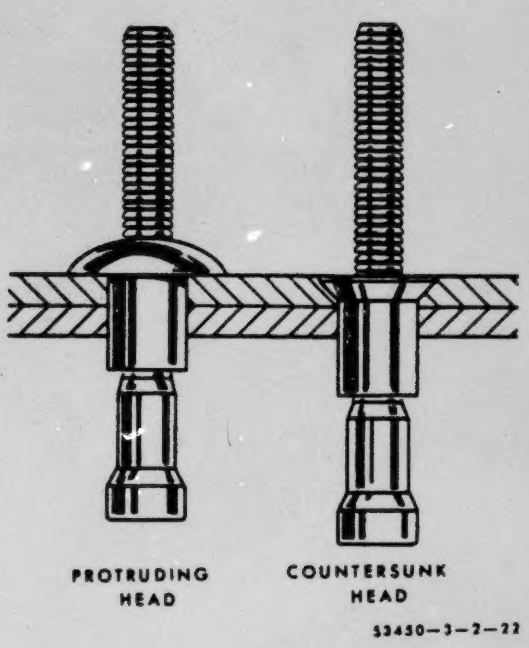

PROTRUDING HEAD
COUNTERSUNK HEAD
53450—3—2—22

Figure 22. Self-plugging (friction lock) rivets.

NOTE: Notice that in the preceding examples, each part number has a portion designated as the grip range. This is the thickness of material that can be satisfactorily joined together with that rivet. As a general rule, this can be exceeded (plus or minus) by $\frac{1}{64}$ inch.

10-15. *Installation tools.* The tools that you use to install self-plugging (friction lock) rivet de-

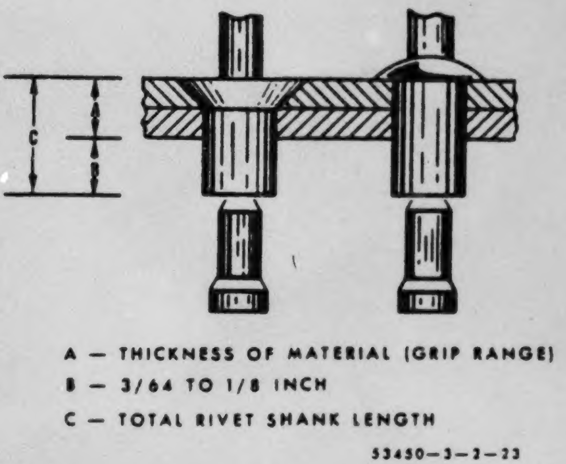

A
B
C
A — THICKNESS OF MATERIAL (GRIP RANGE)
B — 3/64 TO 1/8 INCH
C — TOTAL RIVET SHANK LENGTH
53450—3—2—23

Figure 23. Determining blind rivet length.

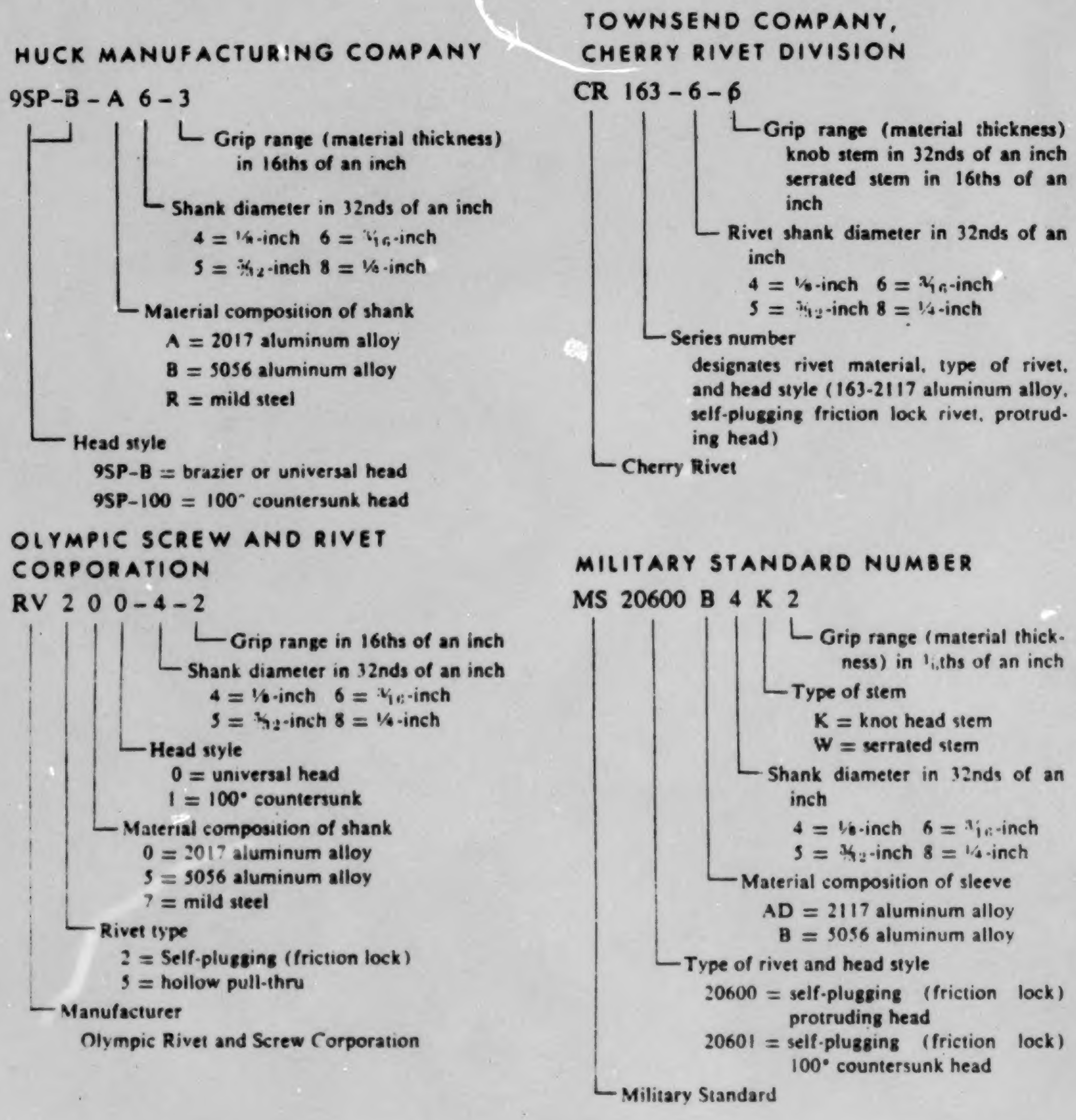
pends upon the manufacturer of the rivet that is being installed. Each company has special tools which are used to insure satisfactory results with their product. Hand tools as well as pneumatic tools are available.

10-16. After selection or determination of the rivet to be used in any installation, determine the proper size twist drill. Generally, manufacturers recommend the following finish drill sizes for the common shank diameters:

–4 #30 drill
–5 #20 drill
–6 #10 drill
–8 F drill

10-17. Exercise care when drilling the material. Hold the drill at right angles to the work at all times to keep from drilling an elongated hole. The self-plugging (friction lock) rivet will not expand as much as a solid shank rivet. If the hole is too large or elongated, the shank will not properly fill the drilled hole. Common hand- or pneumatic-powered drills available to airframe personnel are used to drill the holes. Some manufacturers recommend predrilling the holes; others do not.

10-18. Equipment used to pull the stem of the rivet, as previously stated, depends upon the manufacturer of the rivet. Both manually operated and



HUCK MANUFACTURING COMPANY

9SP-B – A 6 – 3

Grip range (material thickness) in 16ths of an inch

Shank diameter in 32nds of an inch
4 = ⅛-inch 6 = 3/16-inch
5 = 5/32-inch 8 = ¼-inch

Material composition of shank
A = 2017 aluminum alloy
B = 5056 aluminum alloy
R = mild steel

Head style
9SP-B = brazier or universal head
9SP-100 = 100° countersunk head

TOWNSEND COMPANY, CHERRY RIVET DIVISION

CR 163 – 6 – 6

Grip range (material thickness) knob stem in 32nds of an inch serrated stem in 16ths of an inch

Rivet shank diameter in 32nds of an inch
4 = ⅛-inch 6 = 3/16-inch
5 = 5/32-inch 8 = ¼-inch

Series number designates rivet material, type of rivet, and head style (163-2117 aluminum alloy, self-plugging friction lock rivet, protruding head)

Cherry Rivet

OLYMPIC SCREW AND RIVET CORPORATION

RV 2 0 0 – 4 – 2

Grip range in 16ths of an inch

Shank diameter in 32nds of an inch
4 = ⅛-inch 6 = 3/16-inch
5 = 5/32-inch 8 = ¼-inch

Head style
0 = universal head
1 = 100° countersunk

Material composition of shank
0 = 2017 aluminum alloy
5 = 5056 aluminum alloy
7 = mild steel

Rivet type
2 = Self-plugging (friction lock)
5 = hollow pull-thru

Manufacturer
Olympic Rivet and Screw Corporation

MILITARY STANDARD NUMBER

MS 20600 B 4 K 2

Grip range (material thickness) in 1/16ths of an inch

Type of stem
K = knot head stem
W = serrated stem

Shank diameter in 32nds of an inch
4 = ⅛-inch 6 = 3/16-inch
5 = 5/32-inch 8 = ¼-inch

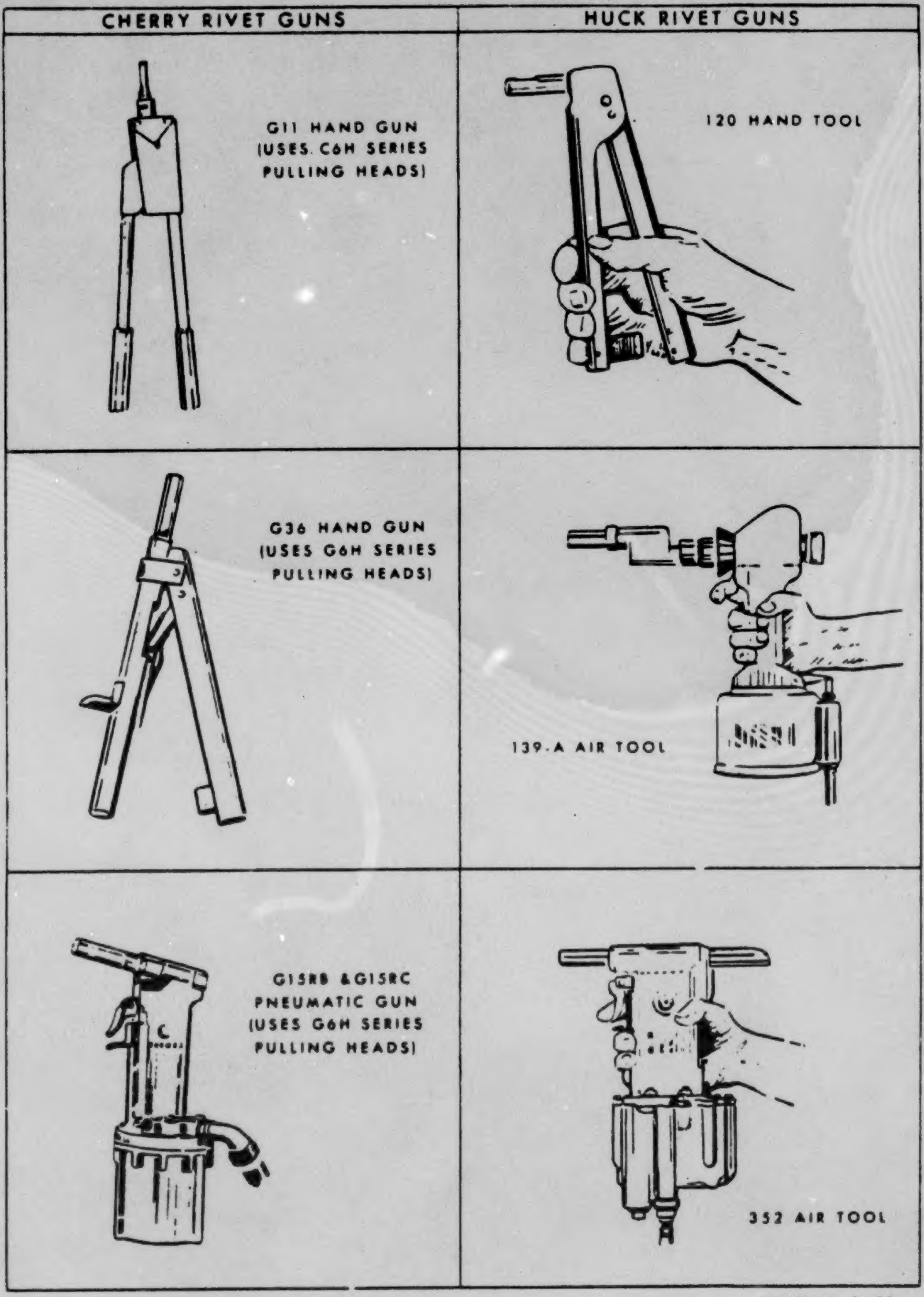
Material composition of sleeve
AD = 2117 aluminum alloy
B = 5056 aluminum alloy

Type of rivet and head style
20600 = self-plugging (friction lock) protruding head
20601 = self-plugging (friction lock) 100° countersunk head

Military Standard

53450–3–2–24

Figure 24. Breakdown of self-plugging (friction lock) rivet code numbers.


CHERRY RIVET GUNS
HUCK RIVET GUNS
G11 HAND GUN (USES C6H SERIES PULLING HEADS)
120 HAND TOOL
G36 HAND GUN (USES G6H SERIES PULLING HEADS)
139-A AIR TOOL
G15RB &G15RC PNEUMATIC GUN (USES G6H SERIES PULLING HEADS)
352 AIR TOOL

53450—3—2—25

Figure 25. Self-plugging (friction lock) rivet guns.

power-operated guns are manufactured for this purpose. Nomenclature for the various tools and assemblies available depends upon the manufacturer. Application and use of the equipment is basically the same. Whether called a hand tool, air tool, hand gun, or pneumatic gun (as illustrated in fig. 25), all of these are used with but one goal—the proper installation of a rivet.

10-19. The portion of the tool or gun that is of prime importance to you is the part that is placed on the rivet. Whether called a nose assembly or sleeve and drawbolt, always assure yourself that you selected the size that is the same as the rivet shank diameter.

10-20. Pneumatic tools operate on the same air pressure as pneumatic riveting hammers, 90 to 100 psi. Follow the operational procedures and adjustments recommended by the manufacturer.

10-21. After installation of the self-plugging (friction lock) rivet, trim the stem flush with the rivet head. Use a pair of diagonal pliers ground smooth on the cutting side. Press the pliers down tight against the rivet head to cut the stem as close to the head as possible. Use a flat file to further smooth the stem, but be careful not to file into the head itself. Stem trimmers and stem saws are available to trim the stem. If aerodynamic smoothness is a factor, the stem can be shaved with a rivet shaver. Again be careful that you do not cut into the head proper.

10-22. *Installation procedures.* The sequence of steps to follow in the installation of self-plugging (friction lock) rivets is basically the same as that for solid shank rivets, but the methods and equipment used vary. The following steps are typical of any installation:

Select the rivet to be installed.

a. Determine by thickness of material to be riveted.

b. Determine by the strength desired in assembly.

c. Determine by location of installation (protruding or countersunk head).

Drill the hole(s).

a. Determine size of twist drill to be used by shank diameter of the rivet.

b. Exercise care when drilling the holes to prevent elongation.

c. Remove all burrs from the material.

d. If countersinking is necessary, use a stop countersink if available.

Install the rivet.

a. Insert the selected rivet in the drilled hole, making sure the rivet head is seated firmly against the metal.

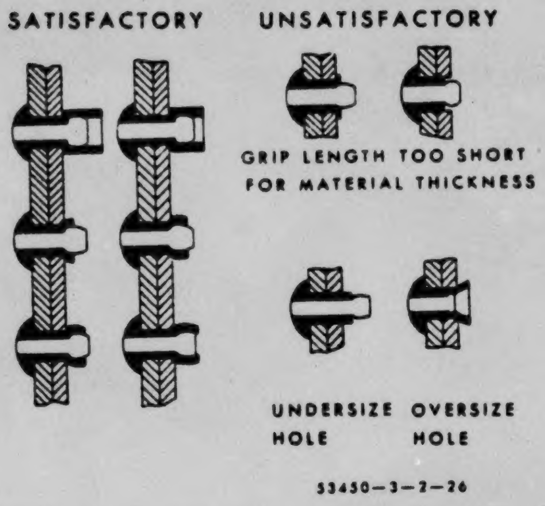


Figure 26. Self-plugging (friction lock) rivet inspection.

b. Position the tool selected on the stem of the rivet. The type of tool selected is determined by the shank diameter of the rivet, manufacturer of the rivet, and number of rivets to be installed.

c. Apply pulling force to the stem of the rivet until the stem snaps.

d. Check the installation of the rivet by applying approximately 15-pound pressure to the end of the stem.

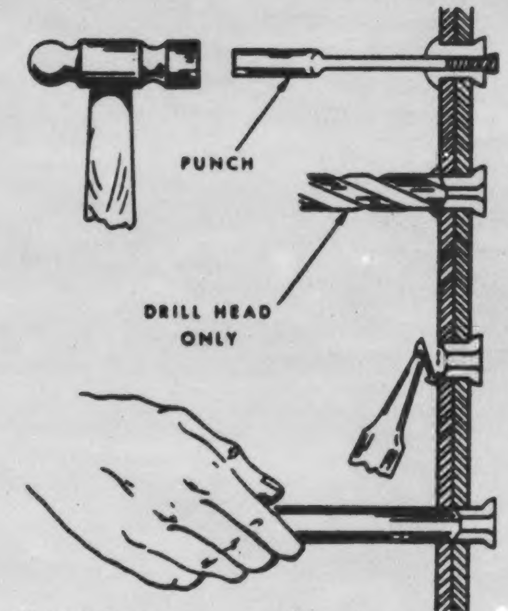
e. Trim the stem flush with the head of the rivet.

10-23. *Inspection.* The inspection of installed self-plugging (friction lock) rivets is very limited. Often the only inspection that can be made is on the head of the rivet. The head of the rivet must fit tightly against the metal. The stem of the rivet should be trimmed flush with the head of the rivet whether it is a protruding head or countersunk head.

10-24. If you can see the shop head side of the installed rivet, inspect it for the requirements illustrated in figure 26. When the rivet head is classified as unsatisfactory, remove the rivet and install another in its place.

10-25. *Removal procedures.* Self-plugging (friction lock) rivets are removed in the same manner as solid shank rivets except for the preliminary step of driving out the stem, illustrated in figure 27. Use the following steps in their proper sequence:

- Punch out the rivet stem with a pin punch.
- Drill out the rivet head, using a drill the same size as the rivet shank.
- Pry off the weakened rivet head with a pin punch.



53450-3-2-27

Figure 27. Self-plugging (friction lock) rivet removal.

- Push out the remainder of the rivet shank with a punch. If the shank will not push out, drill the shank, taking care not to enlarge the hole in the material.

10-26. **Self-Plugging (Mechanical Lock) Rivets.** Self-plugging (mechanical lock) rivets are similar to self-plugging (friction lock) rivets except for the manner in which they are retained in the material. This type of rivet has a positive mechanical locking collar, illustrated in figure 28, which resists vibration that would cause the friction lock rivets to loosen and possibly fall out. Also, the mechanical locking type rivet stem breaks off flush with the head and usually does not require further stem trimming when properly installed. Self-plugging (mechanical lock) rivets display all the strength characteristics of solid-shank rivets and in almost all cases can be substituted rivet for rivet.

10-27. *Fabrication.* Self-plugging (mechanical lock) rivets are fabricated in two sections: (1) a head and shank (including a conical recess and locking collar in the head) and (2) a serrated stem that extends through the shank. Unlike the friction lock type rivet, the mechanical lock rivet has a locking collar that forms a positive lock for retention of the stem in the shank of the rivet. This collar is seated in position during the installation of the rivet.

10-28. Three operations are performed in the installation of the rivet. When a pulling force is exerted on the stem, it is pulled into position; this action tightens the rivet heads (manufactured and shop heads) against the material. At a predetermined point, an inner anvil incorporated in the driving assembly forces the locking collar into position in the manufactured head; and the rivet stem snaps off approximately even with the head of the rivet. Figure 28 illustrates the final position of the locking collar in the rivet head.

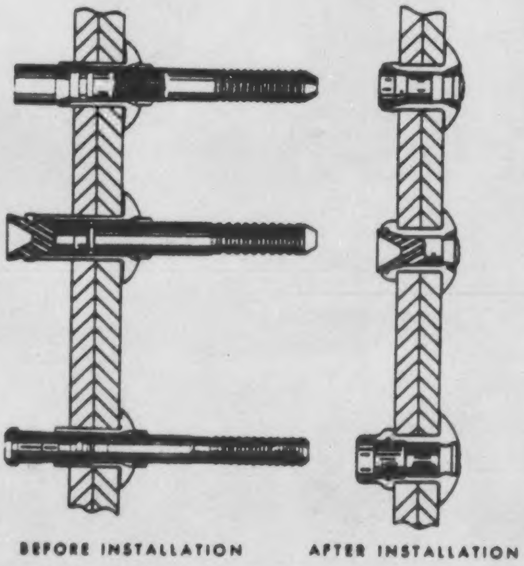
10-29. *Composition.* Self-plugging (mechanic lock) rivets are available from at least two manufacturers. They are fabricated with sleeves (rivet shanks) of 2017 and 5056 aluminum alloys, Monel, and stainless steel.

10-30. *Use.* The mechanical lock type of self-plugging rivet can be used in the same applications as the friction lock type of rivet. In addition, because of its greater stem-retention characteristic, installation in areas subject to excess vibration is recommended.

10-31. *Selection.* The same general requirements must be met in the selection of the mechanical lock rivet as for the friction lock rivet. Composition of the material being joined together determines the composition of the rivet sleeve—2017 aluminum alloy rivets for most aluminum alloys and 5056 aluminum rivets for magnesium, etc.

10-32. Shank diameter of the rivet selected is determined by the thickness of the material and the strength of the joint desired. Too large a diameter should not be used in thin material.

10-33. The length of the selected rivet shank is determined by the thickness of the material (grip



53450-3-2-28

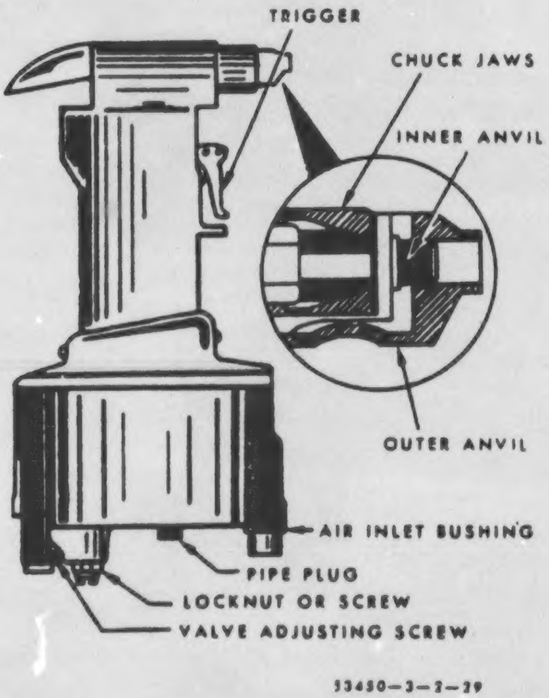
Figure 28. Self-plugging (mechanical lock) rivets.

range) being riveted. The different manufacturers designate the grip range for their product by symbols stamped either on the head of the rivet or on the stem. Tables, available from the manufacturers, furnish you the numbering or lettering system used by each and the minimum and maximum grip ranges for the various diameters available.

10-34. Both the Cherry Lock rivets (manufactured by the Cherry Rivet division) and the Conical Keystone Lock rivet (CKL rivet manufactured by the Huck Manufacturing Company) use grip ranges measured in thousandths of an inch. The variation between the maximum grip range for one rivet and the minimum grip range of the next longer length rivet is so small that you will have no difficulty in procuring the proper length for any installation.

10-35. It is recommended that the thickness of the material being riveted be figured in thousandths of an inch. This method will make it much easier to determine the rivet to select for installation. The grip range designation for self-plugging (mechanical lock) rivets is based on the minimum or maximum thickness of material in which that particular rivet can be installed and conform to specifications.

10-36. *Installation tools.* Self-plugging (mechanical lock) rivets require special driving assemblies. It is best to use tools manufactured by the company that produces the rivet.



53450—3—2—29

Figure 29. Huck model CP350 rivet pull tool.

TABLE 4
MODEL CP350 OPERATING PRESSURES

RIVET DIAMETER	SHIFT VALVE OPERATING PRESSURE
1/8	30–31 psi
5/32	40–47 psi
3/16	66–67 psi

53450 3 2 T4

10-37 The Huck CKL rivet is installed by using the model CP 350 blind rivet tool (available from the Huck Manufacturing Company and illustrated in fig. 29). Notice that the nose of the tool includes: a set of chuck jaws which fit the serrated grooves on the rivet seam and pull it through the rivet shank to drive the rivet; and outer anvil which bears against the outer portion of the manufactured head during the driving operation; and an inner anvil which advances automatically to drive the locking collar into position after the blind head is formed.

10-38. A change in rivet diameter requires a change in chuck jaws, outer anvil, and inner thrust bearing, and an adjustment of the shift operating pressure. Adjustment procedures are specified by the manufacturer. If a manual is not available, the following procedures for adjustment of a model CP350 can be followed:

a. Remove pipe plug from tool cylinder and connect a pressure gage to the tool.

b. Press tool trigger and release it the instant a pull of exhaust indicates that the shift valve controlling the inner valve has shifted. The gage will then indicate the shift pressure. The trigger must be released immediately as the valve shifts. Otherwise, the gage will record the higher pressure which builds up as soon as the valve shifts. (Approximate pressures are contained in table 4.)

c. To adjust the pressure, loosen the valve adjusting screw locknut setscrew and turn the valve adjusting screw (clockwise to increase pressure, counterclockwise to decrease pressure) until the desired pressure is obtained. Check the pressure after tightening the valve adjusting screw locknut setscrew. When rivets of extremely long grip range are to be driven, adjust the high pressure limit. For efficient operation of the tool, the minimum desired line pressure should not be less than 90 psi and the maximum not more than 110 psi.

10-39. Cherry Lock rivets are installed by use of the H-610 pulling head, illustrated in figure 30, developed by the Cherry Rivet Division, Townsend Company. A separate pulling head is needed for each diameter of rivet being installed. The H-610 pulling head is made for use with standard

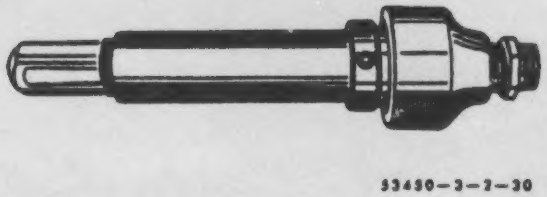


Figure 30. H-610 pulling head.

power and hand guns developed by the same company. It has no need for air pressure regulators, no special pressure setting for different diameters, and there is no need for concern about variations in air pressure.

10-40. *Installation procedures.* Procedures used in installing self-plugging (mechanical lock) rivets are basically the same as those used for installing the friction lock type of rivets. Precautions to be observed are:

a. Be sure the correct grip range is selected.

b. Always use the correct nose assembly or pulling tool for the diameter rivet selected. (For the CKL rivet, check the tool air pressure for the correct setting.)

c. When inserting the rivet in the tool and the material. hold a slight pressure against the head of the rivet.

d. Determine that the rivet is completely driven before lifting the tool from the rivet head. (The stem should snap.)

e. Check each rivet after the driving sequence has been completed for proper stem breakage. (The rivet stem should snap off even with the head of the rivet.)

10-41. *Inspection.* Visual inspection of the seating of the pin in the manufactured head is the most reliable and simplest means of inspecting mechanical lock rivets. If the proper grip range has been used and the locking collar and broken end of the stem are approximately flush with the manufactured head, the rivet has been properly upset and the lock formed. Insufficient grip length is indicated by the stem breaking below surface of the manufactured head. Excessive grip length is indicated by the stem breaking off well above the manufactured head. In either case, the locking collar might not be seated properly, thus forming an unsatisfactory lock.

10-42. *Removal procedures.* Removal of the mechanical lock rivet can easily be accomplished by following the procedures illustrated in figure 31.

10-43. **Pull-Thru Rivets.** This type of blind mechanically expanded rivet is used as a tacking rivet to attach assemblies to hollow tubes, and as a grommet. It differs from the two rivets previously

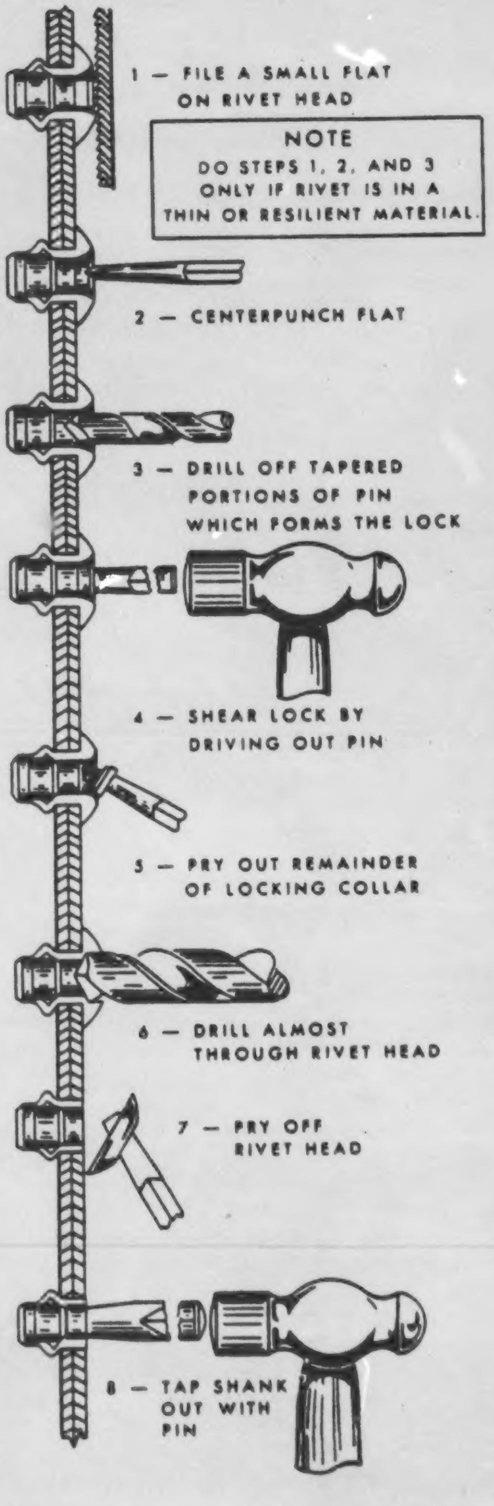

1 — FILE A SMALL FLAT ON RIVET HEAD
NOTE
DO STEPS 1, 2, AND 3 ONLY IF RIVET IS IN A THIN OR RESILIENT MATERIAL.
2 — CENTERPUNCH FLAT
3 — DRILL OFF TAPERED PORTIONS OF PIN WHICH FORMS THE LOCK
4 — SHEAR LOCK BY DRIVING OUT PIN
5 — PRY OUT REMAINDER OF LOCKING COLLAR
6 — DRILL ALMOST THROUGH RIVET HEAD
7 — PRY OFF RIVET HEAD
8 — TAP SHANK OUT WITH PIN

Figure 31. Self-plugging (mechanical lock) rivet removal.

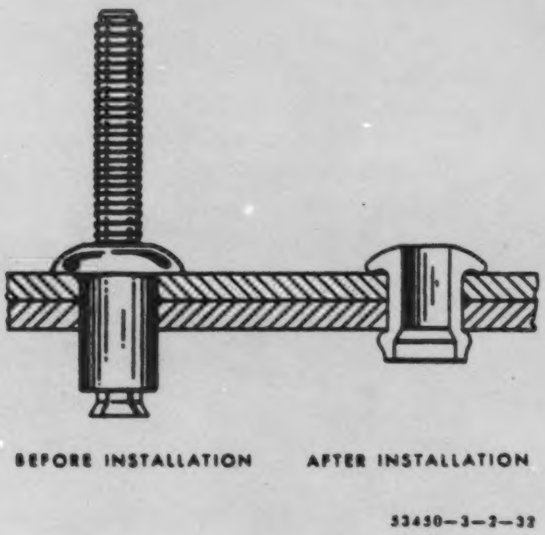


Figure 32. Pull-thru rivet.

discussed in that the stem pulls completely through the sleeve of the rivet during installation. It is structurally weak because of the hollow center after installation is completed. Methods and procedures for installation, inspection, and removal are not discussed here because of the small amount of use for this type rivet in the airframe field. Figure 32 illustrates a typical rivet before and after installation.

10-44. *Rivnuts.* This is the trade name of a hollow blind rivet made of 6053 aluminum alloy, counterbored and threaded on the inside. Rivnuts are installed by one person using a special tool which heads the rivet on the blind side of the material, as illustrated in figure 33. The Rivnut is threaded on the mandrel of the heading tool and inserted in the rivet hole. The heading tool is held at right angles to the material, the handle is squeezed and the mandrel crank is turned clockwise after each stroke. Continue squeezing the handle and turning the mandrel crank of the heading tool until you feel a solid resistance, indicating that the rivet is set.

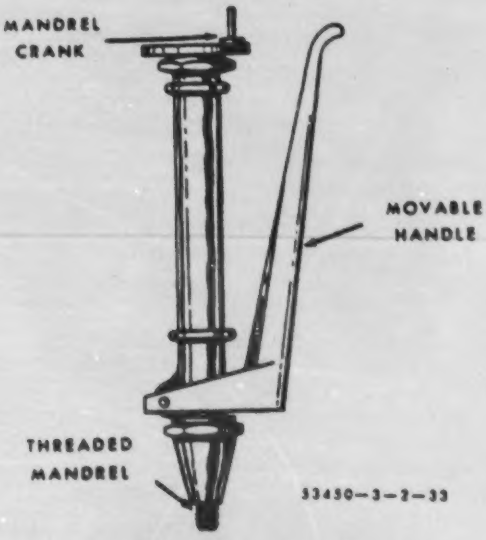


Figure 33. Rivnut heading tool.

10-45. The Rivnut is used primarily as a nut plate and also for attaching deicer boots to leading edges. It may be used as a rivet in secondary structures or for the attachment of accessories such as brackets, instruments, and soundproofing materials. These Rivnuts may be used on some primary structures if proper authorization is obtained.

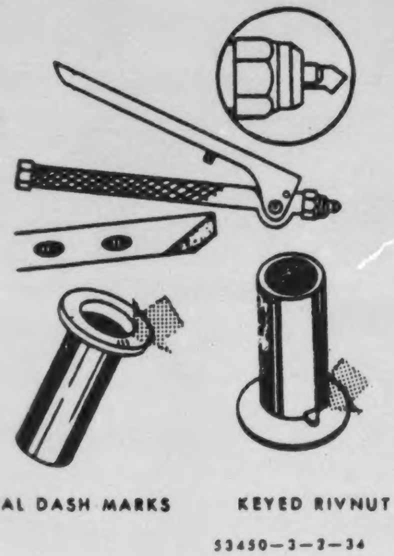


Figure 34. Keyed Rivnut and keyway cutter.

10-46. Rivnuts are manufactured in two head styles and ends: the flat head with open or closed end, and the countersunk head with open or closed end. All Rivnuts, except the thin head (.048-inch) countersunk type, are available with or without small projections (keys) attached to the head to keep the Rivnut from turning. Keyed Rivnuts are used for service as a nut plate, while those without keys are used for straight blind riveting repairs where no torque loads are imposed. A keyway cutter is needed when installing Rivnuts which have keys, and is illustrated in figure 34.

10-47. The countersunk style Rivnut is made with two different angles: the 100° with .048- and .063-inch head thickness, and the 115° with .63-inch head thickness. Each of these head styles is made in three sizes: 6-32, 8-32, and 10-32.

308

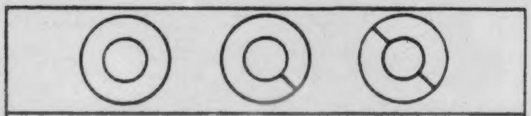
These numbers represent the machine screw size of thread on the inside of the Rivnut. The actual outside diameter of the shanks are $\frac{3}{16}$ inch for the 6–32 size, $\frac{7}{32}$ inch for the 8–32 size, and ¼ inch for the 10–32.

10-48. Open-end Rivnuts are the most widely used and are recommended in preference to the closed-end type for all repairs. However, closed-end Rivnuts must be used in pressurized compartments.

10-49. *Coding.* Rivnuts are manufactured in six grip ranges. The minimum grip length is indicated by a plain head, and the next higher grip length by one radial dash mark on the head. From this size on, each succeeding grip range is indicated by an additional radial dash mark, as shown at the top of table 5, until five marks indicate the maximum range.

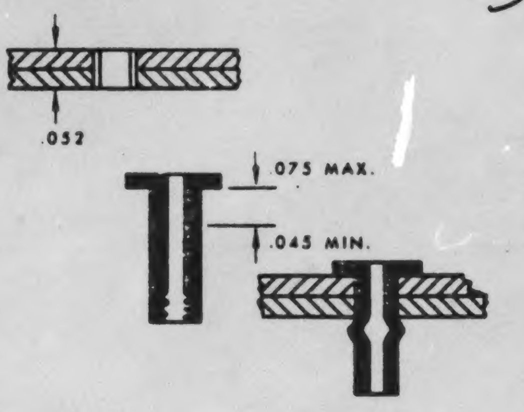
10-50. Notice in table 5 that some code numbers consist of a 6, an 8, or a 10, a dash, and two or three more numbers. In some, the dash is replaced by the letters "K" or "KB." The first number indicates the machine screw size of the thread, and the last two or three numbers indicate the maximum grip length in thousandths of an inch. A dash between the figures indicates that the Rivnut has an open end and is keyless; a "B" instead of the dash means it has a closed end and is keyless; a "K" means it is open and has a key; and a "KB" indicates that it has a closed end and a key. If the last two or three numbers are divisible by 5, the Rivnut has a flat head; if they are not divisible by 5, the Rivnut has a countersunk head.

TABLE 5
RIVNUT DATA TABLE



FLAT-0.32 HEAD THICKNESS		
6-45 8-45 10-45 6B45 8B45 10B45 6K45 8K45 10K45 6KB45 8KB45 10KB45	6-75 8-75 10-75 6B75 8B75 10B75 6K75 8K75 10K75 6KB75 8KB75 10KB75	6-100 8-100 10-100 6B100 8B100 10B100 6K100 8K100 10K100 6KB100 8KB100 10KB100
100 -0.48 HEAD THICKNESS		
6-91 8-91 10-91 6B91 8B91 10B91	6-121 8-121 10-121 6B121 8B121 10B121	6-146 8-146 10-146 6B146 8B146 10B146
100 -0.63 HEAD THICKNESS		
6-106 8-106 10-106 6B106 8B106 10B106 6K106 8K106 10K106 6KB106 8KB106 10KB106	6-136 8-136 10-136 6B136 8B136 10B136 6K136 8K136 10K136 6KB136 8KB136 10KB136	6-161 8-161 10-161 6B161 8B161 10B161 6K161 8K161 10K161 6KB161 8KB161 10KB161

53450-3-2-T5



53450—3—2—35

Figure 35. Determining Rivnut grip length.

10-51. For example, suppose you need a Rivnut for a pressurized compartment, the thickness of the material to be riveted is .080-inch, the shank size has to accommodate a number 10 screw, and the Rivnut must have a closed end with a key and a countersunk head. You would determine the code number as follows:

Screw and thread size = 10–32
Closed end and key = KB
Thickness of material = .080
Grip length = .106 or 106

10-52. The head is countersunk because the grip length number 106 is not divisible by 5. Writing out the complete code number, you get 10KB106. Since this size is the minimum grip length, the Rivnut would have a plain head.

10-53. *Installation equipment.* Tools used in the installation of Rivnuts include the hand-operated heading tools, the pneumatic power Rivnut driver, and the keyway cutter. All heading tools have a threaded mandrel onto which the Rivnut is threaded until the head of the Rivnut is against the anvil of the heading tool.

10-54. Hand-operated heading tools are made in three types: straight, 45°, and 90°. The pneumatic power driving tools are made in two types:

319

lever throttle and offset handle. With the power tool, the threading, upsetting, and withdrawal or unthreading are accomplished by compressed air through the manipulation of fingertip controls. The keyway cutter is for cutting keyways only. In some instances, the keyway cutter cannot be used because the material may be too thick. If such is the case, use a small round file to form the keyway.

10-55. *Selection.* The important factors to be considered in selecting Rivnuts are grip range, style of head, condition of Rivnut end, and the presence or absence of a key.

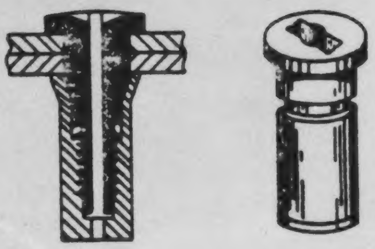
10-56. Proper grip length is the most important of these conditions. The objective when installing this type of rivet is to produce an ideal bulge on the blind side of the work without distorting any of the threads inside the Rivnut. In other words, be sure the bulge takes place between the first thread of the rivet and the lower edge of the riveted material. The space between the ideal bulge and the upper thread (where the gripping takes place) is considered the grip range.

10-57. Note the procedure to follow when determining the grip range. The total thickness of the sheets in figure 35 is .052 inch. By referring to the chart in table 5, you learn that 6–75 is the grip length to choose since the maximum grip length of the preceding size (6–45) is only .045 inch and would be too short. The grip length of the 6–75 Rivnut actually ranges from .045 inch, the maximum length of the preceding size (6–45), to .075 inch, which is the maximum grip length of the 6–75 Rivnut (see fig. 35).

10-58. When selecting head style, use the same rules as for solid-shank rivet application. Select key type Rivnuts whenever screws are to be inserted, and use closed-end Rivnuts only in special places, such as sealed compartments of flotation bays or supercharged compartments.

10-59. *Preparation.* Drilling holes for Rivnuts requires the same precision as for solid-shank rivets. The shank of the Rivnut must fit snugly in the hole. To obtain the best results for a flathead installation, first drill a pilot hole smaller than the shank diameter of the Rivnut and then ream it to the correct size. This procedure insures a smooth, round hole.

10-60. If keyed Rivnuts are used, cut the keyway after the hole has been reamed. In cutting the keyway, hold the keyway cutter so it makes a 90° angle with the work. Also, cut the keyway on the side of the hole away from the edge of the sheet, especially when the Rivnut is used on the outside row. Operate the keyway cutter by inserting it in the hole and squeezing the handles.



33450—3—2—36

Figure 36. Internally threaded rivet (two piece).

10-61. The use of flush Rivnuts is limited. For metal which has a thickness greater than the minimum grip length of the first rivet of a series, use the machine countersink; and for metal thinner than the minimum grip length of the first rivet, use the dimpling process. Don't use the countersunk Rivnut unless the metal is thick enough for machine countersinking, or unless the underside is accessible for the dimpling operation.

10-62. For a countersunk Rivnut, the sheets to be joined can usually be machine countersunk. This method is preferred because the bearing surface in a dimpled hole in one sheet of average gage will normally occupy the entire gripping surface of the Rivnut, thus limiting its grip range to that of an anchored nut only. Aside from the countersinking operation, the procedure for installing a flush Rivnut is the same as that for the flathead Rivnut.

10-63. *Application.* When installing Rivnuts, among the things to check is the threaded mandrel of the heading tool to see that it is free from burrs and chips from the previous installation. Then screw the Rivnut on the mandrel until the head touches the anvil. Insert the Rivnut in the hole (with the key positioned in the keyway, if a key is used) and hold the heading tool at right angles to the work. Press the head of the Rivnut tightly against the sheet while slowly squeezing the handles of the heading tool together until the Rivnut starts to head over. Then release the handle, and screw the stud further into the Rivnut. This prevents stripping the threads of the Rivnut before it is properly headed. Again squeeze the handles together until the Rivnut heading is complete. Now remove the stud of the heading tool from the Rivnut by turning the crank counterclockwise.

10-64. The action of the heading tool draws the Rivnut against the anvil, causing a bulge to form in the counterbored portion of the Rivnut on the inaccessible side of the work. This bulge is comparable to the shop head on an ordinary solid shank rivet. The amount of squeeze required to head the Rivnut properly is best determined by practice. Avoid stripping the thread in the Rivnut.

10-65. *Special operations.* The installation of a Rivnut is incomplete unless it is plugged either with one of the plugs designed for that purpose or with a screw used for attaching purposes. A Riv-

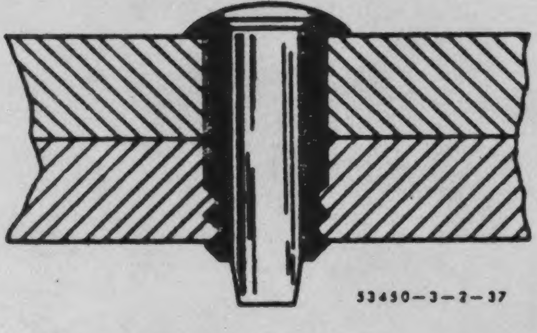


Figure 37. Deutsch rivet.

nut does not develop its full strength when left hollow.

10-66. Three types of screw plugs can be used: the 100° countersunk screw plug, the headless screw plug, and the thin overhead screw plug. The 100° countersunk and the headless screw plugs have either a Phillips or a Reed and Prince recess. The oval head either has a common screw driver slot, a Phillips, or a Reed and Prince. All screw plugs are made of high-tensile SAE steel and are cadmium plated.

10-67. The same tools are used for installation of the splined Rivnut as for installation of the standard types, but the pull-up stud of the heading tool must be adjusted to accommodate the longer shank.

10-68. **Dil Lok-Skrus and Dill Lok-Rivets.** Dill Lok-Skru and Lok-Rivet, illustrated in figure 36, are trade names for internally threaded rivets (two piece). They are used for blind attachment of such accessories as fairings, fillets, access door covers, door and window frames, floor panels, and the like. Lok-Skrus and Lok-Rivets are similar to the Rivnut in appearance and application. Lok-Skrus and Lok-Rivets, however, come in three parts and require more clearance on the blind side than the Rivnut to accommodate the barrel.

10-69. The Lok-Rivet and the Lok-Skru are alike in construction, except that you tap the Lok-Skru internally for fastening an accessory by using an attaching screw. On the other hand, the Lok-Rivet is not tapped and can be used only as a rivet. Since both Lok-Skrus and Lok-Rivets are installed in the same manner, the discussion below for the Lok-Skru also applies to the Lok-Rivet.

10-70. The three main parts of a Lok-Skru are the barrel, the head, and an attachment screw. The barrel is made of aluminum alloy and comes in either closed or open ends. The head is either aluminum alloy or steel, and the attachment screw is made of steel. All steel parts are cadmium plated, and aluminum parts are anodized to resist corrosion. When installed, the barrel screws up over the head and grips the metal on the blind side. The attaching screw is then inserted if needed.

10-71. The three head types most commonly used are the flush, flat, and countersunk. The Lok-Skru is also available in hexagon and spacer head types. (The Lok-Rivet comes only with flat and flush heads.) The head is tapped for 7–32, 8–32, 10–32, or 10–24 screws, and the diameters vary from .230 inch for 6–32 screws, to .292 inch for 10–32 screws. Grip ranges vary from .010 inch to .225 inch.

10-72. *Installation equipment*. Special hand- and air-operated power tools are required for installation of Lok-Skrus. An interchangeable barrel blade fits into the blade handle and is held in place by a setscrew. The barrel blade has a flattened portion which fits into a slot in the end of the Lok-Skru barrel. The head driver has projections which fit into recesses in the Lok-Skru head. Head drivers and blades are interchangeable for use with various sizes and styles of Lok-Skrus.

10-73. *Preparation and application*. The drilling procedure for Lok-Skrus is identical to that for common, solid-shank rivets. To install the Lok-Skru, insert the Lok-Skru tool so that the blade extends through the barrel slot and the driver sets firmly in the head slot. Insert the fastener in the drilled hole. Fit the ratchet handle assembly together and adjust the pawl lever for proper ratchet direction. Hold the ratchet handle stationary and turn the barrel blade handle to the left until the barrel is drawn firmly against the sheet on the opposite side. Press the tool firmly against the Lok-Skru to hold the tool blade and driver in the slots.

10-74. Stop turning the barrel handle when the Lok-Skru barrel has been drawn against the sheet. Finally, tighten by an additional quarter-turn or less on the ratchet handle, drawing the head into the sheet. This time, hold the blade handle stationary while turning the ratchet handle. Test the tightness of the installation with an ordinary 8-inch screwdriver ground round on the end. Attachments are made by using the attaching screw and a regular screwdriver.

10-75. For more specific information on selection of internally threaded rivets (two piece), installation tools, and installation procedures, consult Technical Order 1–1A–8.

10-76. **Deutsch Rivets.** This rivet is a high-strength blind rivet used on late model aircraft. It has a shear strength of 75,000-psi minimum and can be installed by one man.

10-77. The Deutsch rivet consists of two parts, the stainless-steel sleeve and the hardened steel drive pin, illustrated in figure 37. The pin and sleeve are coated with a lubricant and a corrosion inhibiter.

10-78. The Deutsch rivet is available in diameters of 3/16, ¼, and ⅜ inch. Grip lengths for this

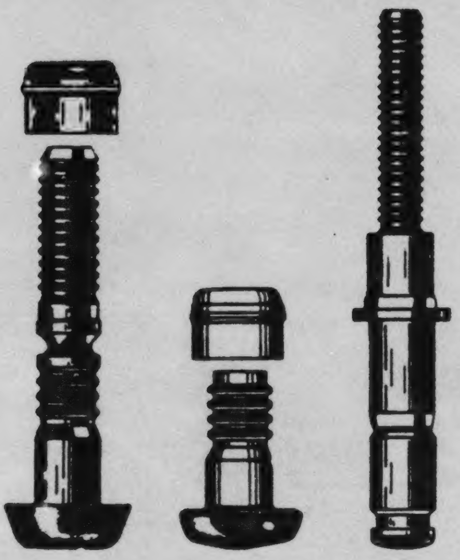


Figure 38. Lockbolt types.

rivet range from $\frac{3}{16}$ to 1 inch. Some variation is allowed in grip length when you are installing the rivet; for example, a rivet with a grip length of $\frac{3}{16}$ inch can be used where the total thickness of materials is between .198 and .228 inch.

10-79. *Installation procedures.* In driving a Deutsch rivet, use an ordinary hammer of a pneumatic rivet gun and a flathead set. Seat the rivet in the previously drilled hole and then drive the pin into the sleeve.

NOTE: If the Deutsch rivet is driven into a tight hole, use a hollow drift punch to seat the rivet against the material. The punch must clear the drive pin and rest against the head of the rivet to prevent premature expansion of the sleeve and head.

10-80. The driving action causes the pin to exert pressure against the sleeve and forces the sides of the sleeve out. This stretching forms a shop head on the end of the rivet and provides a positive fastening action for the fastener. The ridge on the top of the rivet head locks the pin into the rivet as the last few blows are struck.

10-81. Never shave or mill the head of the Deutsch rivet. Milling or shaving destroys the locking action of the ring on top of the rivet head.

10-82. Another feature of the Deutsch rivet is that it can be installed without going all the way through the second piece of material. However, this type of installation is not recommended unless the second piece is very thick.

10-83. One of the main restrictions to the use of the Deutsch rivet is that no bucking tool is used to take up the shock of driving. The structure where installation is made must be heavy and solid enough to support the driving forces.

10-84. *Rivet removal.* If a Deutsch rivet that extends through the material is to be removed, use the same procedures you would use to remove a solid shank rivet. Use a drill to drill off the head. Use a drift punch slightly smaller than the diameter of the drive pin to drive out the pin. Use a drive punch slightly smaller than the diameter of the sleeve to drive the sleeve out of the material.

10-85. If the rivet does not extend through the material, drill out the drive pin to approximately one-half its depth. Then tap the hole and finish drilling out the remainder of the pin. Next, insert a screw through a spacer and tighten the screw into the sleeve. Continue tightening the screw until the sleeve is removed.

11. Huck Lockbolt

11-1. The lockbolt is a form of bolt which combines the features of a high-strength bolt and rivet and has advantages over both. The lockbolt is generally used in wing splice fittings, landing gear fittings, fuel cell fittings, longerons, beams, skin splice plates, and other major structural attachments. It is easier and quicker to install than the conventional rivet or bolt and eliminates the use of lockwashers, cotter pins, and special nuts. Like the rivet, lockbolts require a pneumatic hammer or pull gun for installation. When the lockbolt is properly installed, it is rigidly and permanently locked in place.

11-2. **Types.** The three types of lockbolts commonly used are: the pull, the stump, and the blind types. These types are illustrated in figure 38.

11-3. Pull type lockbolts are mainly used in aircraft primary and secondary structures. They are installed very rapidly and have approximately one-half the weight of equivalent AN steel bolts and nuts. A special pneumatic pull gun is required to install this type lockbolt. Since bucking is not required to install this lockbolt, one person can accomplish the job.

11-4. In figure 38, notice that the stump type lockbolt does not have the extended stem with pull grooves. Stump lockbolts, although they do not have the extended stem with pull grooves, are companion fasteners to pull type lockbolts. Stump lockbolts are used primarily where clearance does not permit installation of pull type lockbolts. A standard pneumatic riveting hammer (with a hammer set attached for swaging the collar into the pin locking grooves) and a bucking bar are required to install stump type lockbolts.

Pull type lockbolt

ALPP H T 8 8

- Grip length in 16ths of an inch
- Body diameter in 32nds of an inch
- Pin materials
  - E = 75S-T6 alum alloy
  - T = heat treated alloy steel
- Class fit
  - H = hole filling (interference fit)
  - N = non-hole filling (clearance fit)
- Head Type
  - Act509 = close tolerance AN509 C-sink head
  - ALPP = pan head
  - ALPB = brazier head
  - ALP509 = standard AN509 C-sink head
  - ALP426 = standard AN426 C-sink head

Stump type lockbolt

ALSF E 8 8

- Grip length in 16ths of an inch
- Body diameter in 32nds of an inch
- Pin material
  - E = 75S-T6 alum alloy
  - T = heat treated alloy steel
- Head Type
  - ASCT509 = close tolerance AN509 C-sink head
  - ALSF = flat head type
  - ALS509 = standard AN509 C-sink head
  - ALS426 = standard AN426 C-sink head

Blind type lockbolt

BL 8 4

- Grip length in 16ths of an inch ± 1/32-inch
- Diameter in 32nds of an inch
- Blind lockbolt

Lockbolt collar

LC C 8

- Diameter of pin in 32nds of an inch
- *Material
  - C = 24ST aluminum alloy (green color)
  - F = 61ST aluminum alloy (plain color)
  - R = mild steel (cadmium plated)
- Lockbolt collar

*Use 24ST alum alloy with heat treated alloy lockbolts only.

Use 61ST alum alloy with 75ST alum alloy lockbolts only.

Use mild steel with heat treated alloy steel lockbolts for high temperature applications only.

Figure 39. Numbering system for lockbolts.

11-5. Blind type lockbolts come as complete units or assemblies. They have exceptional strength and sheet pull-together characteristics. Blind lockbolts are used where only one side of the work is accessible and, generally, where it is difficult to drive a conventional rivet. This type of lockbolt is installed in the same manner as the pull type lockbolt.

11-6. Common features of the three types of lockbolts are the annular locking grooves on the pin and the locking collar, which is swaged into the pin's lock grooves to lock the pin in tension. The pins of the pull and blind type lockbolts are extended for pull installation. The extension is provided with pulling grooves and a tension break-off groove.

11-7. **Composition.** The pins of pull and stump type lockbolts are made of heat-treated alloy steel or high-strength aluminum alloy. Companion collars are made of aluminum alloy or mild steel. The blind lockbolt consists of a heat-treated alloy steel pin, blind sleeve and filler sleeve, mild steel collar, and carbon steel washer.

11-8. **Substitution.** Alloy steel lockbolts may be used to replace steel Hi-Shear rivets, solid steel rivets, and AN bolts of the same diameter and head type. Aluminum alloy lockbolts may be used to replace solid aluminum alloy rivets of the same diameter and head type. Steel and aluminum alloy lockbolts may also be used to replace steel and 2024T aluminum alloy bolts, respectively, of the same diameter. Blind lockbolts may be used to replace solid aluminum alloy rivets, stainless steel rivets, and all blind rivets of the same diameter.

TABLE 6
PULL AND STUMP TYPE LOCKBOLT GRIP RANGES

GRIP NR.	GRIP RANGE		GRIP NR.	GRIP RANGE	
	Min.	Max.		Min.	Max.
1	.031	.094	17	1.031	1.094
2	.094	.156	18	1.094	1.156
3	.156	.219	19	1.156	1.219
4	.219	.281	20	1.219	1.281
5	.281	.344	21	1.281	1.344
6	.344	.406	22	1.344	1.406
7	.406	.469	23	1.406	1.469
8	.469	.531	24	1.469	1.531
9	.531	.594	25	1.531	1.594
10	.594	.656	26	1.594	1.656
11	.656	.718	27	1.656	1.718
12	.718	.781	28	1.718	1.781
13	.781	.843	29	1.781	1.843
14	.843	.906	30	1.843	1.906
15	.906	.968	31	1.906	1.968
16	.968	1.031	32	1.968	2.031
			33	2.031	2.094

53450-3-2 TB

TABLE 7
BLIND TYPE LOCKBOLT GRIP RANGES

1/4 INCH DIAMETER			5/16 INCH DIAMETER		
GRIP NR	GRIP RANGE		GRIP NR.	GRIP RANGE	
	MIN.	MAX.		MIN.	MAX.
1	.031	.094	2	.094	.156
2	.094	.156	3	.156	.219
3	.156	.219	4	.219	.281
4	.219	.281	5	.281	.344
5	.281	.344	6	.344	.406
6	.344	.406	7	.406	.469
7	.406	.469	8	.469	.531
8	.469	.531	9	.531	.594
9	.531	.594	10	.594	.656
10	.594	.656	11	.656	.718
11	.656	.718	12	.718	.781
12	.718	.781	13	.781	.843
13	.781	.843	14	.843	.906
14	.843	.906	15	.906	.968
15	.906	.968	16	.968	1.031
16	.968	1.031	17	1.031	1.094
17	1.031	1.094	18	1.094	1.156
18	1.094	1.156	19	1.156	1.219
19	1.156	1.219	20	1.219	1.281
20	1.219	1.281	21	1.281	1.343
21	1.281	1.343	22	1.343	1.406
22	1.343	1.406	23	1.406	1.469
23	1.406	1.469	24	1.460	1.531
24	1.469	1.531			
25	1.531	1.594			

53450-3-2-T9

11-9. **Numbering System.** The numbering system for the various three types of lockbolts is explained in figure 39.

11-10. **Grip Range.** The bolt grip range required for any application is determined by measuring the thickness of the material with a hook scale inserted through the hole. Once this measurement is determined, the correct grip range can be selected by referring to tables 6 and 7.

11-11. **Installing Tools.** The CP352 and CP353 rivet pull guns are used to install pull and blind type lockbolts. You will need the proper-size swaging set, a pneumatic riveting hammer, and a bucking bar when installing the stump type lockbolts.

11-12. **Installing Procedures.** After selection of the proper grip range and type of lockbolt, and the tools necessary for installation, the fastener can easily be installed by the procedures illustrated in the following figures:

Pull type lockbolt—figure 40
Stump type lockbolt—figure 41
Blind type lockbolt—figure 42

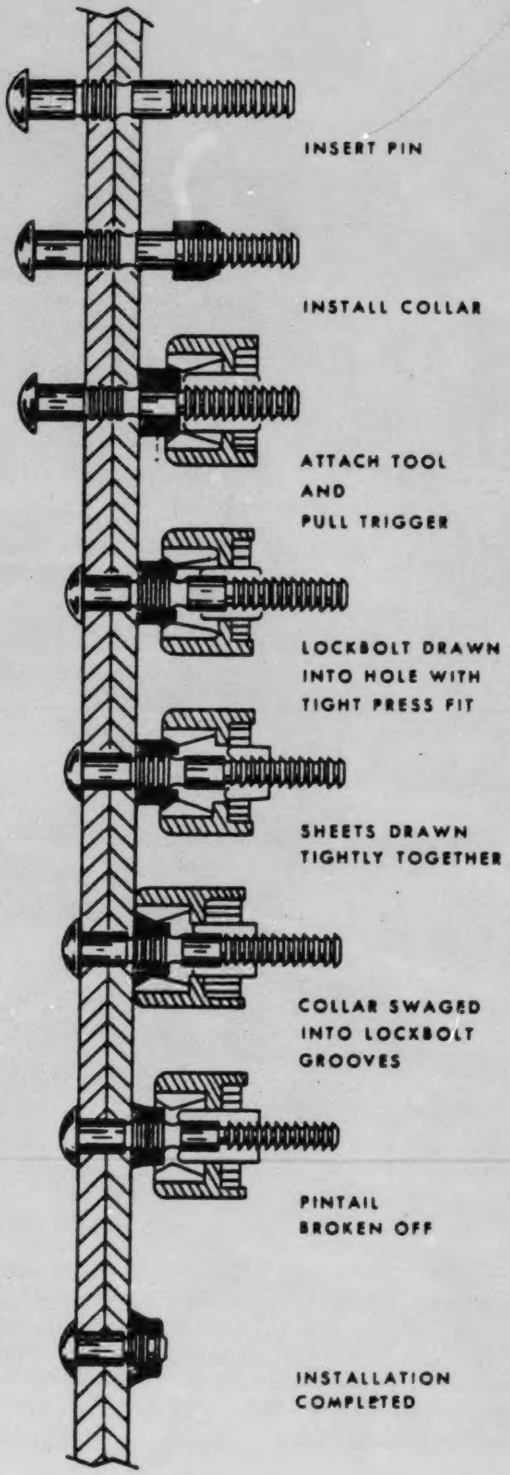

INSERT PIN
INSTALL COLLAR
ATTACH TOOL AND PULL TRIGGER
LOCKBOLT DRAWN INTO HOLE WITH TIGHT PRESS FIT
SHEETS DRAWN TIGHTLY TOGETHER
COLLAR SWAGED INTO LOCKBOLT GROOVES
PINTAIL BROKEN OFF
INSTALLATION COMPLETED

Figure 40. Pull type lockbolt installation.

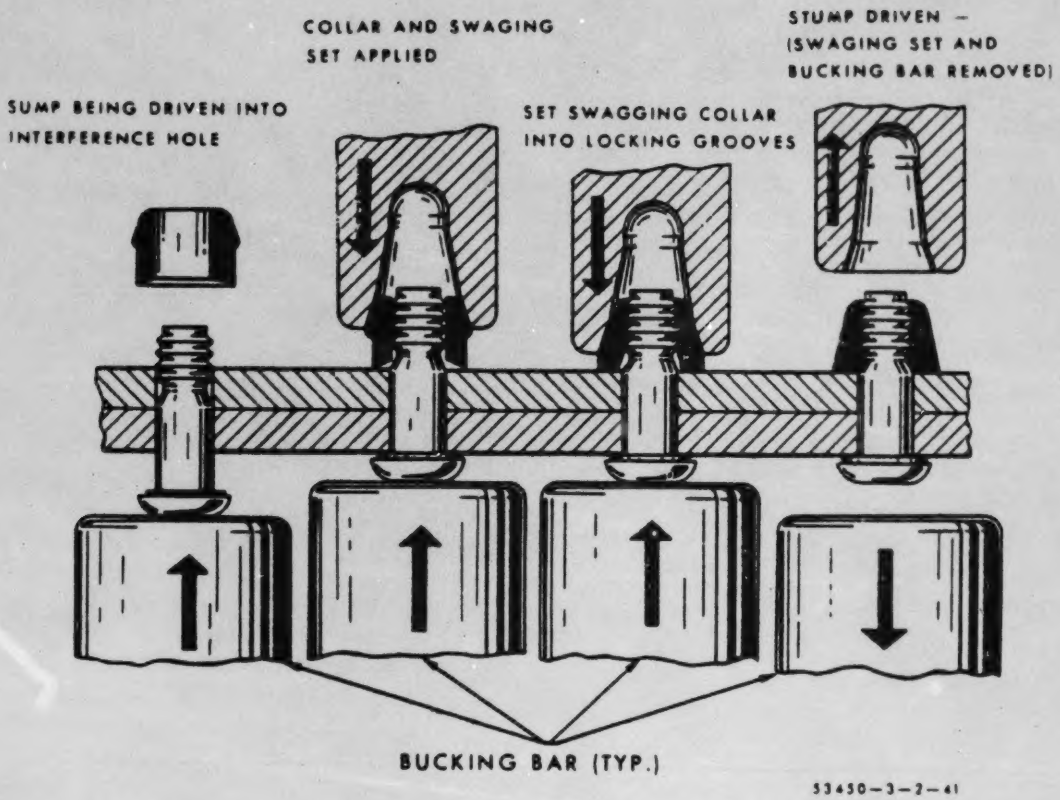


Figure 41. Stump type lockbolt installation.

11-13. **Inspection.** The lockbolt collar should be swaged substantially throughout the complete length of the collar. The tolerance of the broken end of the pin relative to the top of the collar must be within dimensions given in table 8.

11-14. **Removal.** When removal of a lockbolt becomes necessary, remove the collar by splitting it axially with a sharp cold chisel. Be careful not to break out or deform the hole. Use of a backup bar on the opposite side of the collar being split is recommended. Drive out the pin with a drift punch.

12. Turnlock Fasteners

12-1. Many locations on the aircraft must be accessible for necessary inspections and maintenance of the various aircraft components. The use of turnlock fasteners makes possible quick and easy removal or installation of cowling, fairings, inspection plates, and access doors. Turnlock fasteners are not strong enough to withstand primary structural stresses and are not used to fasten these structures. The three styles of turnlock fasteners used by the Air Force are: style I (Dzus), style II (Camloc), and style III (Airloc).

12-2. **Turnlock Fastener—Style I.** The style I turnlock fastener consists of a stud, grommet, and a receptacle. Figure 43 illustrates an installed style I fastener and the various parts.

12-3. The grommet is made of aluminum or aluminum-alloy material. It acts as a holding device for the stud. Grommets can be fabricated from 1100 aluminum tubing if none are available from normal sources.

12-4. The spring is made of cadmium-plated steel to prevent corrosion. The spring supplies the force that locks or secures the stud in place when two assemblies are joined.

12-5. Studs are fabricated from steel and are cadmium plated. They are available in three head styles: wing, flush, and oval. Body diameter,

TABLE 8
TABLE OF TOLERANCES

Pin Diameter	Tolerance		
	Below		Above
3/16	.079	to	.032
1/4	.079	to	.050
5/16	.079	to	.050
3/8	.079	to	.060

53450-3-2-110

length, and head type are identified or determined by the markings found on the head of the stud. Figure 44 illustrates these markings. The diameter is measured in sixteenths of an inch. Stud length is measured in hundredths of an inch and is the distance from the head of the stud to the bottom of the spring hole.

12-6. *Installation procedures.* The following are typical procedures for installing style 1 turnlock fasteners:

a. Punch or drill a hole in the plate or part of the assembly that is to receive the stud. The hole should be approximately the same diameter as the shank of the selected fastener. It is permissible to exceed this dimension a maximum of $\frac{1}{32}$ inch. Remove all burrs and sand the hole smooth before dimpling or installing the grommet.

b. If the fastener to be installed is the flush type, dimple the material with dimpling dies or a female die and a stud as the male die.

c. Insert the grommet into the hole from the bottom side, as illustrated in the A view of figure 45.

d. Clench the grommet in place by the use of dies, as shown in the B view of figure 45.

e. Insert the stud into the grommet and secure it in place by the use of a block of wood and a female die, as illustrated in the C view of figure 45.

f. Punch a hole in the opposite piece of material approximately $\frac{3}{16}$ inch larger than the hole punched for the stud. Remove all burrs and sand smooth the edge of the hole. Dimple the hole just enough to allow the grommet to clear when the assembly is locked together.

g. Center the spring over the hole. Mark and drill two holes for the rivets. Install the spring with countersunk rivets.

12-7. *Removal and replacement procedures.* Broken, damaged, or worn springs, grommets, or studs must be removed and replaced.

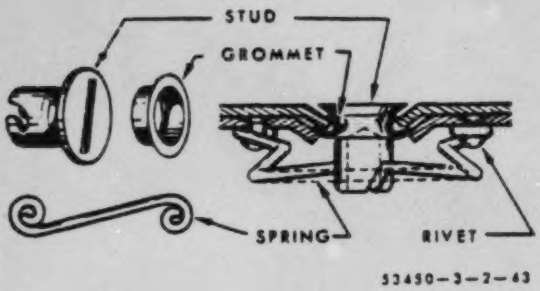

STUD
GROMMET
SPRING
RIVET
53450-3-2-43

Figure 43. Turnlock fastener—style I.

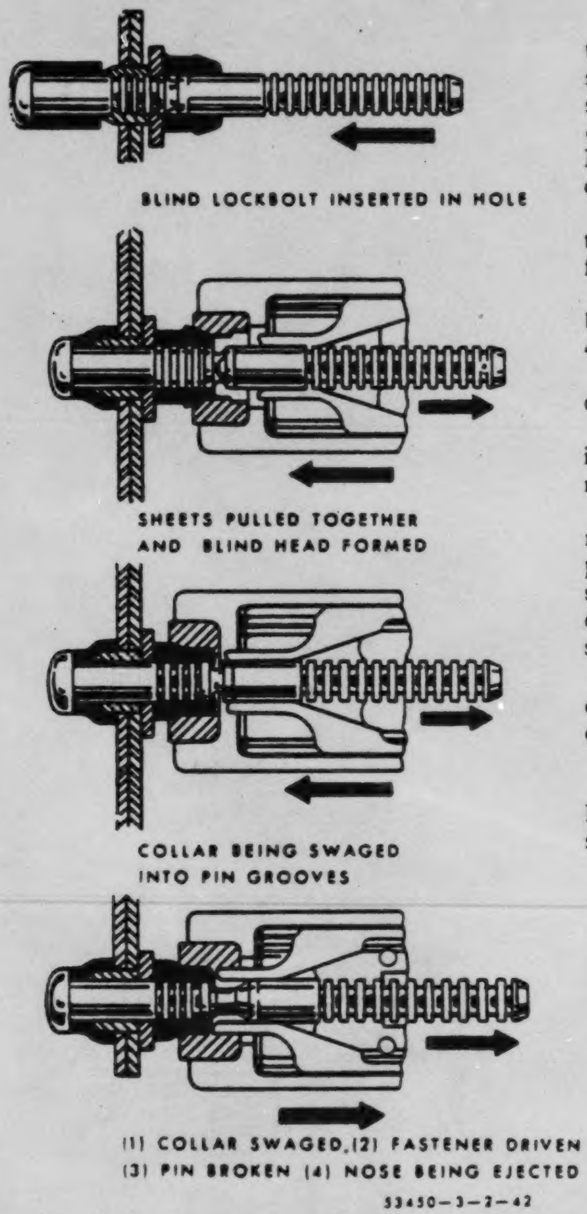

BLIND LOCKBOLT INSERTED IN HOLE
SHEETS PULLED TOGETHER AND BLIND HEAD FORMED
COLLAR BEING SWAGED INTO PIN GROOVES
(1) COLLAR SWAGED,(2) FASTENER DRIVEN (3) PIN BROKEN (4) NOSE BEING EJECTED
53450-3-2-42

Figure 42. Blind type lockbolt installation.

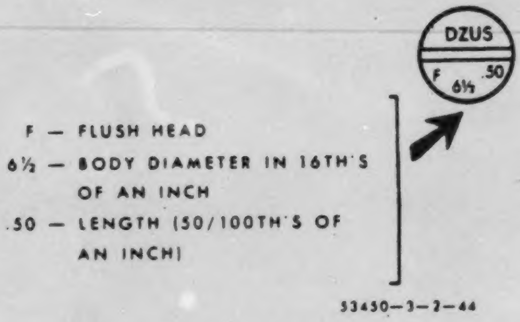
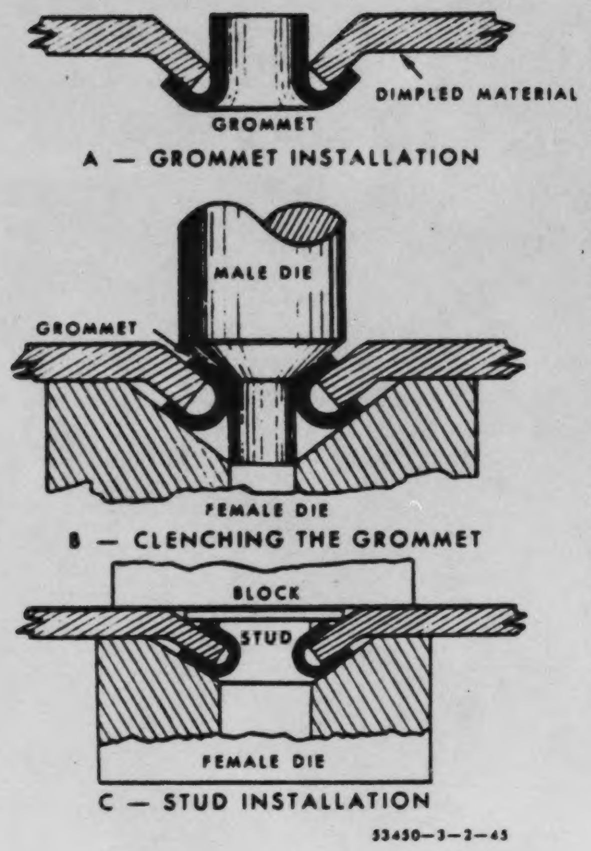

DZUS
F
6½
.50
F — FLUSH HEAD
6½ — BODY DIAMETER IN 16TH'S OF AN INCH
.50 — LENGTH (50/100TH'S OF AN INCH)
53450-3-2-44

Figure 44. Style I identification.



A — GROMMET INSTALLATION

B — CLENCHING THE GROMMET

C — STUD INSTALLATION

Figure 45. Turnlock fastener—style I installation.

12-8. Springs may be removed and replaced by drilling out the old rivets and installing new springs.

12-9. Loose or worn grommets may be removed by cutting with a chisel or similar tool. Install a new grommet in the same hole, using the same procedures as those used for the original installation.

12-10. Broken or cracked studs may be removed by driving the stud through the hole using a wooden block or mallet. Be careful to keep from damaging the hole. New studs can be installed by the same procedures as those used for installation of the original stud.

12-11. Cracked or badly damaged dimples may be repaired by fabrication and installation of a patch plate.

12-12. **Turnlock Fastener—Style II.** The style II turnlock fastener is used to secure aircraft cowling and fairing. It consists of three parts: a stud assembly, a grommet, and a receptacle (see fig. 46). The two types of receptacles available are the rigid and the floating type. Since the rigid type is not used to a great extent, replace it with the floating type when replacement becomes necessary.

12-13. The stud assembly illustrated in figure 46 consists of a stud cross-pin, spring, and spring cup. It is assembled at the factory and is never disassembled. The grommet is a flanged ring made to fit into a dimple in the outside panel. Grommets are available in various lengths to accommodate the different thicknesses of panels. To install the stud in the grommet, compress the spring with a pair of Camloc pliers, and with a twisting motion insert the stud assembly into the grommet.

12-14. *Installation procedures.* Prepare a hole in the panel or piece of material to receive the grommet. Punch the hole approximately $\frac{1}{32}$ inch smaller than the outside diameter of the grommet. Burr and sand the edges smooth to avoid cracking during the dimpling operations. Select male and female dimpling dies of the correct size to dimple the hole. Insert the grommet into the dimpled hole from the top and press the dimple down tight against the flange of the grommet. This procedure causes the grommet to be gripped and held securely in place.

12-15. Stud assemblies are manufactured in different lengths to allow for different thicknesses of panels. The length is indicated by a number

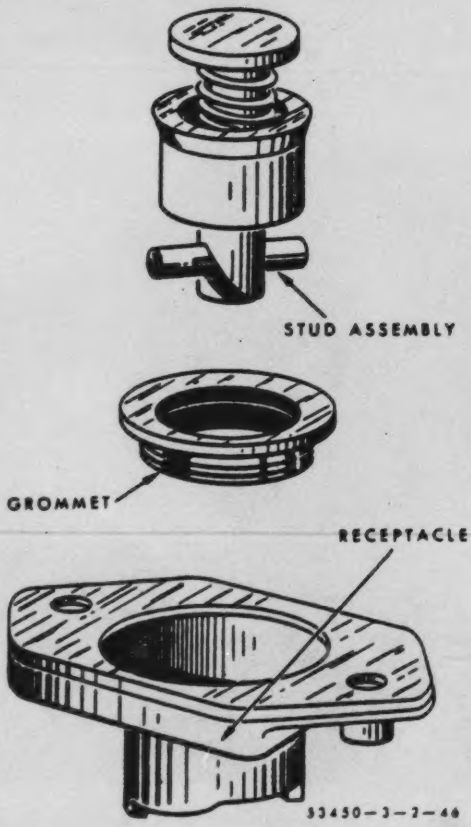


Figure 46. Turnlock fastener—style II.

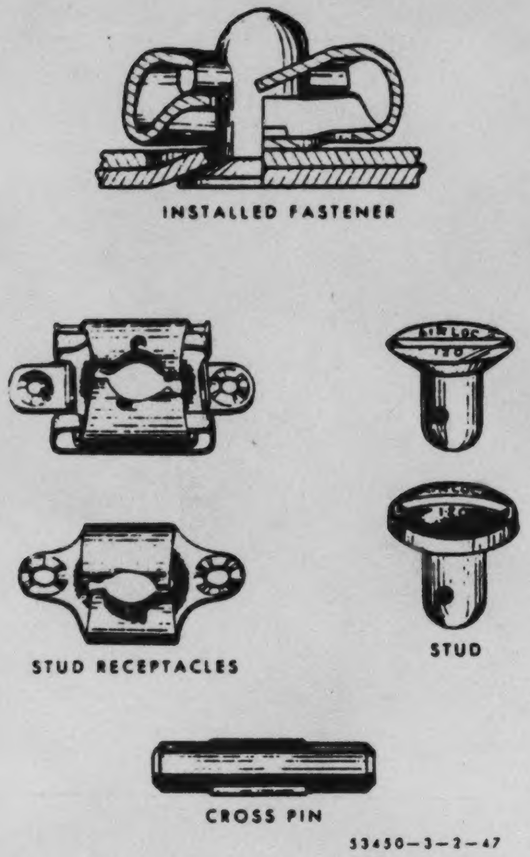


Figure 47. Turnlock fastener—style III.

stamped on the head of the stud. Select the correct length and insert the stud assembly into the grommet, using Camloc pliers to depress the spring of the stud; then with a twisting motion insert the stud into the grommet and release the spring. The stud cannot be removed unless the spring is again depressed.

12-16. Prepare a hole in the piece of material that is to receive the receptacle. The hole should be approximately the same diameter as that in the receptacle. Center the receptacle on the prepared hole and mark the rivet locations. Center-punch, drill, and countersink the rivet holes. Install the receptacle, using flush-head style rivets.

12-17. Check the completed installation for correct length of stud. The stud should not have to be forced to the locking position but should lock with a snug fit and not be too loose.

12-18. *Removal procedures.* When it becomes necessary to remove and replace style II turnlock fasteners. procedures used are similar to those used in installation. Drill the rivets out of the receptacle and install a new one. Use Camloc pliers. Depress the spring of the stud assembly and remove the stud. Install a new one, using the previously explained procedures. If the grommet requires replacement, exercise caution in removing the damaged one. If the hole has not been damaged in removal, dimple the material again and install a new grommet, using the same procedures as used in the original installation. If the hole was damaged in removal, prepare a patch plate and attach it to the material.

12-19. **Turnlock Fastener—Style III.** The style III turnlock fastener, illustrated in figure 47, consists of a stud, a cross pin, and a stud receptacle. The studs are manufactured from steel and are case hardened to reduce excessive wear. The stud hole is reamed for a press fit of the cross pin.

12-20. The total amount of material thickness to be secured with the style III fastener must be known before the correct length of stud can be selected for installation. The total thickness of material that each stud will satisfactorily lock together is stamped on the head of the stud in thousandths of an inch (.040, .070, .190, etc.). Studs are manufactured in three head styles: flush, oval, and wing.

12-21. The cross-pin, illustrated in figure 47, is manufactured from chrome-vanadium steel and is heat-treated to provide maximum strength, wear, and holding power. Never use a pin the second time; once you remove it from the stud, replace it with a new pin.

12-22. Receptacles for style III fasteners are manufactured in two types: rigid and floating. Sizes are classified by number: number 2, number 5, and number 7. They are also classified by the center-to-center distance between the rivet holes of the receptacle: number 2, ¾ inch; number 5, 1 inch; and number 7, 1⅜ inch. Receptacles are fabricated from high-carbon heat-treated steel. An upper wing assures ejection of the stud when unlocked and enables the cross pin to be held in a locked position between the upper wing, cam, stop, and wing detent, regardless of the tension to which the receptacle is subjected.

12-23. *Installation procedures.* To install a flush type style III fastener, first prepare the hole for the stud. The size of the punched hole should be approximately the same as the diameter of the stud shank. Remove all burrs from the edge of the hole and sand smooth before dimpling. Select the correct size male and female dimpling dies and dimple the hole. The dimple should be deep enough to accommodate the head of the stud. Insert the stud in the dimpled hole. Select the proper size tool for the cross pin and insert the pin in the stud.

12-24. Punch a hole in the opposite piece of metal for the receptacle. This hole should be large enough to accommodate the dimple on the opposite piece of material. Center the receptacle on the hole. Locate and mark the center holes for the rivets. Center punch, drill, and countersink the rivet holes. Install the receptacle with countersunk rivets.

12-25. *Removal procedures.* Style III fastener assemblies can be removed by using the correct size Airloc tool to remove the cross pin and then removing the stud. The receptacle can be removed by drilling out the rivets.

CHAPTER 3

Common Attaching Methods

IN THE FABRICATION of aircraft, where riveting is unsuitable or impractical, bolts, nuts, screws, and resistance welding is used to assure sound structure.

2. Bolts are used where great strength is required to join parts which are under high tension or shear—parts on which great pulling forces are exerted. Consequently, the materials from which these bolts are manufactured must be as strong as other materials used in the aircraft. Screws are the most common fasteners used in aircraft. They are similar to other types of fasteners, such as bolts, but differ mainly by usually having a lower material strength, a looser thread fit, and shanks threaded along the entire length. Aircraft nuts are made in many shapes and sizes, of different materials and are available in either right- or left-hand-threads. Nuts do not come with the bolts when bolts are ordered. Both must be ordered separately.

3. Electric resistance welding has solved a production problem with a decrease in labor, dirt, noise, and time. One of the advantages in using this process is definite localization of heating at the junction where fusion is desired with control of both heat and the extent of fusion. The welds are made on a production basis with no loss of material.

4. In this chapter we discuss the identification characteristics, and installation procedures necessary for correct usage of common fasteners. We discuss the do's and don'ts of substitution with other fasteners and items necessary to eliminate unsafe conditions. Further, we discuss the use and theory so that you may obtain a better understanding of the resistance welding machines and processes. You will need the information contained in this chapter so that you may correctly identify and requisition these fasteners and correctly operate the equipment involved.

13. Common Fasteners

13-1. You have studied some of the various fastening devices used to fasten materials together. Some of these fastening devices allow quick dismantling or replacement of aircraft parts that must be taken apart and put back together at frequent intervals. Riveting or welding these parts each time they are serviced soon weakens or ruins the joint. Furthermore, some joints require greater tensile strength and stiffness than rivets can give. Bolts and screws are two types of fastening devices which give the required security and rigidity. Bolts are generally used where great strength is required, and screws where strength is not the deciding factor.

13-2. Bolts and screws are similar in many ways. Both are pins or rods made of aluminum alloy or steel. They are used for fastening or holding, and each has a head on one end and screw threads on the other. Regardless of these similarities, there are several distinct differences between the two types of fasteners.

13-3. The threaded end of a bolt is always blunt; that of a screw may be either blunt or pointed.

13-4. The threaded end of a bolt must have a nut screwed onto it to complete the assembly. The threaded end of a screw may fit into a female receptacle or it may fit directly into the metal being secured.

13-5. A bolt has a fairly short-threaded section and a comparatively long grip length or unthreaded portion. The screw has a longer threaded section and no clearly defined grip length.

13-6. A bolt assembly is generally tightened by turning the nut on the bolt; the head of the bolt may not be designed for turning. A screw is always tightened by turning its head.

13-7. When it becomes necessary to replace aircraft fasteners, use duplicate fasteners if at all possible. If duplicate fasteners are unavailable, use extreme care and caution when making fastener substitution. When fastener substitution is necessary, obtain the services of a competent aeronautical engineer to assist you in making the proper selection or refer to the substitution charts in the applicable technical order.

13-8. **Common Bolts.** Aircraft bolts are fabricated from cadmium- or zinc-plated corrosion-resisting steel, unplated corrosion-resisting steel, and anodized aluminum alloys. Bolts generally used in aircraft structures are classified in two basic groups: common bolts, such as general purpose bolts, close tolerance bolts, and internal wrenching bolts; and special purpose bolts, such as clevis bolts, eyebolts, and Jo-Bolts.

13-9. Threads, common bolts, and machine screws are equipped with inclined threads for the purpose of rotating on a nut which has like threads. There are two general types of threads in use in the United States at this time: National Fine (NF) and National Coarse (NC). (For tables describing NF and NC threads, see TO 1-1A-8.) Both type threads are designated as the number of times the incline (threads) rotate around a given diameter bolt or screw in a 1-inch length of that diameter bolt or screw. For example, a 428 thread indicates that a ¼-inch diameter bolt has 28 threads in 1 inch of its length.

13-10. Threads are also designated by class of fit. By class of fit, we mean how hard the nut turns on the thread. The higher number the fit, the more difficult it is to install the nut. For example, a class 1 fit is a loose fit and can easily be turned on with the fingers. A class 3 fit will require a wrench to turn the nut.

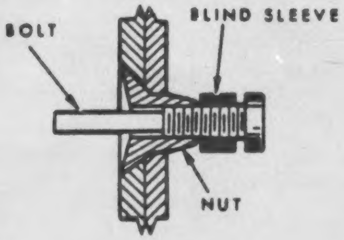
13-11. *General purpose bolts.* This type of aircraft bolt is not machined as carefully as a close tolerance bolt. General purpose bolts are hex-headed and are used in repair work or attachment of assemblies where a light drive fit is permissible (.006-inch clearance for a ⅝-inch hole, and other sizes in proportion). The head may or may not be drilled for safetying and the threaded section of the shank may or may not be drilled for cotter pin securing.

13-12. *Close tolerance bolts.* This type of bolt is machined more accurately than the general purpose bolt. Close tolerance bolts may be hexheaded or have a 100° countersunk head. They are used in applications where a tight drive fit is required (the bolt will move into position only when struck with a 12- to 14-ounce hammer).

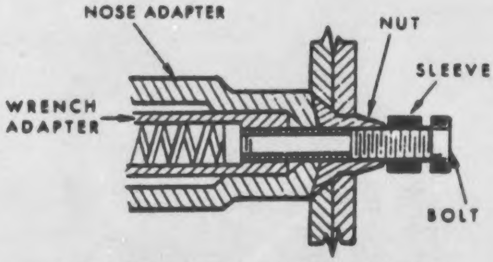
13-13. *Internal wrenching bolts.* These bolts are fabricated from high-strength steel and are used where severe tension occurs. When they are used in steel parts, the bolt hole must be slightly countersunk to seat the large corner radius of the shank at the head. In dural material a special heat-treated washer must be used to provide an adequate bearing surface for the head. The head of the internal wrenching bolt is recessed to allow the insertion of an internal wrench when you are installing or removing the bolt.

13-14. *Identification and coding.* Bolts are manufactured in many shapes and varieties. A clear-cut method of classification is difficult. Bolts can be identified by the shape of the head, method of securing, material used in fabrication, and the expected usage. In your work as an airframe repairman, you will be using aircraft bolts. These are usually identified by their head shape and usage.

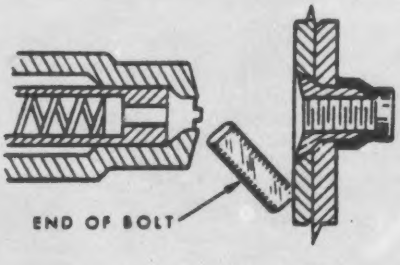
13-15. AN (Army-Navy), NAS (National Aircraft Standards), MS (Military Standards), and AMS (Aerospace Material Specifications) are standards and specifications set up by Government agencies and civilian organizations to govern the manufacture of aerospace materials. The AN and MS Standards are military Standards and are in general use by the respective Government agencies. Many of the AN Standards have been converted to and replaced by MS Standards. The trend is toward the use of MS Standards for mate-



BEFORE DRIVING



NOSE ADAPTER OF DRIVING TOOL MUST BE HELD AT RIGHT ANGLE TO WORK AND FIRM AGAINST JO-BOLT HEAD



AFTER DRIVING

33450-3-2-48

Figure 48. Jo-Bolt.

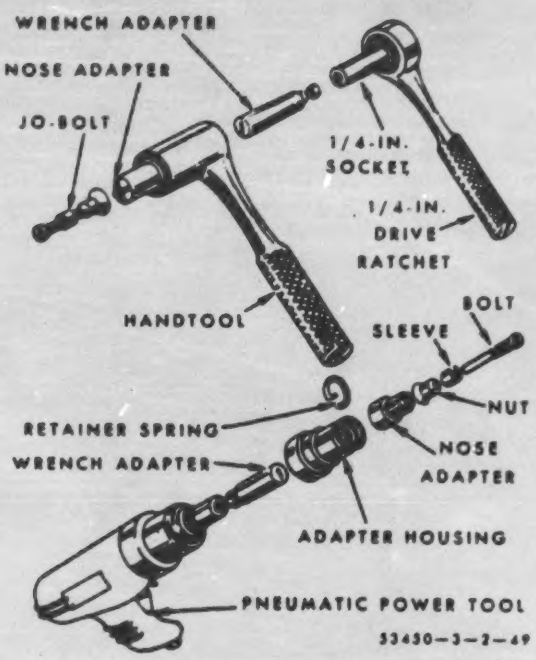


Figure 49. Jo-Bolt tools.

rial designations. Although the NAS and AMS are civilian standards, they are used extensively by the military.

13-16. The code number used for classification of the various bolts tells the style, size of the bolt, material used in manufacture, usage, grip, and length. It also tells if the head is drilled for securing and if the shank is drilled for cotter pin securing. Consult TO 1–1A–8 for tables of the various types of bolts and an explanation of the code numbers used to identify the individual bolts.

13-17. **Special Purpose Bolts.** Bolts manufactured for a particular application or usage are classified as special purpose bolts. Clevis bolts, eyebolts, and Jo-Bolts are special purpose bolts.

13-18. *Clevis bolts.* The head of a clevis bolt is round and is either slotted to receive a common screwdriver or recessed to receive a cross-point screwdriver. This type of bolt is used only where shear loads occur and never in tension. It is inserted as a mechanical pin in a control system. An explanation of the clevis bolt code numbering system is in TO 1–1A–8.

13-19. *Eyebolts.* This special purpose bolt is used where external tension loads are applied. The eye is designed for the attachment of such devices as the fork of a turnbuckle, a clevis, or a cable shackle. The threaded end may or may not be drilled for safetying.

13-20. *Jo-Bolts.* Jo-Bolt is a trade name for a technically classified internally threaded three-piece rivet. Because the trade name has become common language for this type of fastener, we discuss it as such.

13-21. The Jo-Bolt consists of three parts: a threaded steel alloy bolt, a steel alloy nut, and a stainless steel sleeve. (See fig. 48.) The parts are factory assembled. As the Jo-Bolt is installed, the bolt is turned while the nut is held, causing the sleeve to expand over the end of the nut, forming the blind head and clamping against the work. When driving is completed, the bolt breaks off. Applicable technical orders give specified break-off limits to be followed when installing Jo-Bolts.

13-22. The high shear and tension strength of this bolt makes it suitable for use in areas of high stresses where some of the other blind fasteners are not practical. Jo-Bolts are often a part of the permanent structure of late model aircraft. They are used in areas which are not often subjected to replacement or servicing. (Because it is a three-part fastener, it is not used where any part, in becoming loose, could be drawn into the engine air intake.) Other advantages of using Jo-Bolts are excellent resistance to vibration, weight saving, and fast installation by one person.

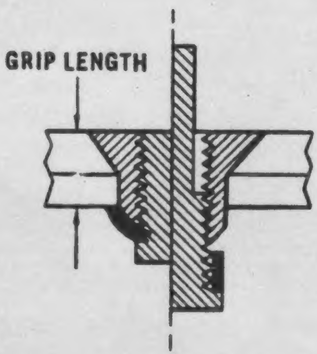
13-23. Presently Jo-Bolts are available in four diameters: the 200 series, approximately ³⁄₁₆ inch in diameter; the 260 series, approximately ¼ inch in diameter; the 312 series, approximately ⁵⁄₁₆ inch in diameter; and the 375 series, approximately ⅜ inch in diameter. Three available head styles are flush (F), hexhead (P), and flush millable (FA).

13-24. Jo-Bolts are installed with special tools and equipment designed specifically for the job (see fig. 49).

13-25. Hole size for the installation of Jo-Bolts should be such that the selected fastener can be

TABLE 9
JO-BOLT GRIP RANGES

Length Dash Number	Grip Length Range
2	.094- .156
3	.157- .219
4	.220- .281
5	.282- .344
6	.345- .406
7	.407- .469
8	.470- .531
9	.532- .594
10	.595- .656
11	.657- .719
12	.720- .781
13	.782- .844
14	.845- .906
15	.907- .969
16	.970-1.031



53430-3-2-T11.

easily pushed through the hole. In no case should it be forcibly driven through the hole. A very light tap is permissible in aluminum alloys but not in steel parts.

13-26. Like all fasteners, the Jo-Bolt selected for installation must be of the correct grip length. It is necessary to use some means of determining the thickness of the material being joined so that the correct grip length can be selected. A hook gage or your knowledge of the thickness of materials can be used in determining the dash number to select. Table 9 is a grip length table and gives the minimum and maximum range for each dash number.

13-27. After selecting the fastener, drilling the hole, and inserting the fastener in the hole, follow these procedures to drive the Jo-Bolt:

a. Select the proper combination of tools to install the fastener selected.

b. Engage the slabbed portion of the bolt shank with the nose adapter of the tool. Make sure the cogs on the nose engage the nut.

AN315 OR AN335 = PLAIN NUT PART NUMBER
4 (4/16) = 1/4—28 SCREW AND THREAD SIZE
C = STAINLESS STEEL (CORROSION RESISTING)
R = RIGHT-HAND THREAD

THE COMPLETE CODE NUMBER FOR ORDERING THE PLAIN NUT WOULD BE AN315C4R

AN316 = PLAIN CHECK NUT PART NUMBER
4 (4/16) = 1/4—28 SCREW AND THREAD SIZE
C = STAINLESS STEEL
R = RIGHT-HAND THREAD

THE COMPLETE CODE NUMBER FOR ORDERING THE PLAIN CHECK NUT WOULD BE AN316C4R

SOME OTHER COMMON NUTS AND THEIR CODE NUMBERS ARE:

CODE NUMBER AN310DD5R
AN310 = AIRCRAFT CASTLE NUT
DD = 2024T ALUMINUM ALLOY
5 = 5/16-INCH IN DIAMETER
R = RIGHT-HAND THREAD (USUALLY 24 THREADS PER INCH)

CODE NUMBER AN320—10
AN320 = AIRCRAFT CASTELLATED SHEAR NUT
= CADMIUM PLATED CARBON STEEL
10 = 5/8-INCH IN DIAMETER (THIS NUT IS USUALLY RIGHT HAND THREAD, 18 THREADS PER INCH)

CODE NUMBER AN350B1032
AN350 = AIRCRAFT WING NUT
B = BRASS
10 = NUMBER 10 BOLT
32 = THREADS PER INCH

53430-3-2-50

Figure 50. Nut numbering system.

c. Hold the driving tool down tight against the head of the Jo-Bolt and perpendicular to the work. Failure to do so may result in the stem breaking off before the Jo-Bolt is tight.

d. Apply power. As power is applied, the bolt is turned while the nut is held. The sleeve, compressed between the bolt head and the control end of the nut, is drawn over the taper. The sleeve is expanded, forming the blind head against the surface of the inner member. As driving is completed, the slabbed portion of the bolt is snapped off and ejected from the tool.

e. Touch up the end of the bolt at the breakoff point, after driving is completed, with zinc chromate primer.

f. Inspect the completed installation for compliance with applicable technical order limits.

13-28. If it is necessary to remove a Jo-Bolt, use procedures similar to those for the removal of solid-shank rivets. The power drill selected should not turn over 500 rpm, and the twist drill used should be large enough to cut the threads out of the nut.

13-29. **Nuts.** Aircraft nuts are manufactured in a variety of shapes and sizes. They are made of cadmium-plated carbon steel, stainless steel, brass, or anodized 2024T aluminum alloy. They may be obtained with right- or left-hand threads.

13-30. Nuts do not come with the bolts when bolts are ordered; they come separated and must be ordered separately. No identifying marking or lettering appears on nuts. They are identified only by the characteristic metallic luster or color of the aluminum, the brass, or the fiber; by their construction; and by thread size.

13-31. Except for a few very special types, nearly all aircraft nuts are Air Force-Navy Standard. In stock lists, part numbers designate the type of nut. The common types and the respective part numbers are: plain, A315 and A335; castle, AN310; plain check, AN 316; light hex, AN 340; and AN 345; and castellated shear, AN320. The patented self-locking types are assigned part numbers ranging from MS20363 through MS20367. *The Boots, the Flexloc, the Fiber Lock Nut, the Elastic Stop Nut, and the steel self-locking nut* belong to this group. Part number AN350 is assigned to the *wing nut.*

13-32. Letters and digits following the part number indicate such items as material, size, threads per inch, and whether the thread is right or left hand. The letter "B" following the part number indicates the nut material to be brass; a "D" indicates it to be 2017T aluminum alloy; a "DD" indicates it to be 2024T aluminum alloy; a "C," stainless steel; and a dash in place of a letter indicates the material to be cadmium-plated carbon steel.

13-33. The digit (or two digits) following the dash or the material code letter is the dash number of the nut, and it indicates the size of the shank and threads per inch of the bolt on which the nut will fit. The dash number corresponds to the first figure appearing in the part number coding of general purpose bolts. A dash number 3, for example, indicates that the nut will fit an AN3 bolt (10–32); a 4 means it will fit an AN4 bolt (¼–28); a 5, an AN5 bolt (5/16–24); and so on.

13-34. The code numbers for self-locking nuts end in three- or four-digit numbers. The last two digits refer to threads per inch, and the one or two digits preceding these two digits stand for the nut size in sixteenths of an inch.

13-35. In stock lists, the full code number is given for each nut, and the corresponding bolt and thread size is also given in another column. If the description appears to need additional clarification, an illustration is included. This arrangement makes the stock list description quite complete and prevents errors in ordering nuts for bolts.

13-36. Let's consider an example of the code numbers used to order aircraft nuts. Suppose you needed a nut to fit a ¼-inch bolt. A stainless steel, plain nut of 28 threads per inch is required. Also needed is a stainless steel check nut. Both are to have right-hand threads. Let us determine the code number to be used in ordering these nuts. Refer to figure 50 to learn how to determine and interpret code numbers.

13-37. Aircraft nuts are divided into two general groups: (1) non-self-locking nuts, which must be safetied by external locking devices such as lock nuts, cotter pins, or safety wire; and (2) self-locking nuts, which contain the locking feature as an integral part.

13-38. *Non-self-locking nuts.* Most of the familiar types of nuts, including the plain nut, the castle nut, the castellated shear nut, the plain hexnut, the light hexnut, and the plain check nut are of the non-self-locking type and are illustrated in figure 51.

13-39. The *castle nut,* AN 310, is used in conjunction with drilled-shank AN hexhead bolts, clevis bolts, eyebolts, drilled head bolts, or studs. It is fairly rugged and can withstand large tensional loads. Slots (called castellations) in the nut are designed to accommodate a cotter pin or lock wire for safetying purposes.

13-40. The *castellated shear nut,* AN 320, is used with devices (such as drilled clevis bolts and threaded taper pins) which are normally subjected to shearing stress only. Like the castle nut, it is

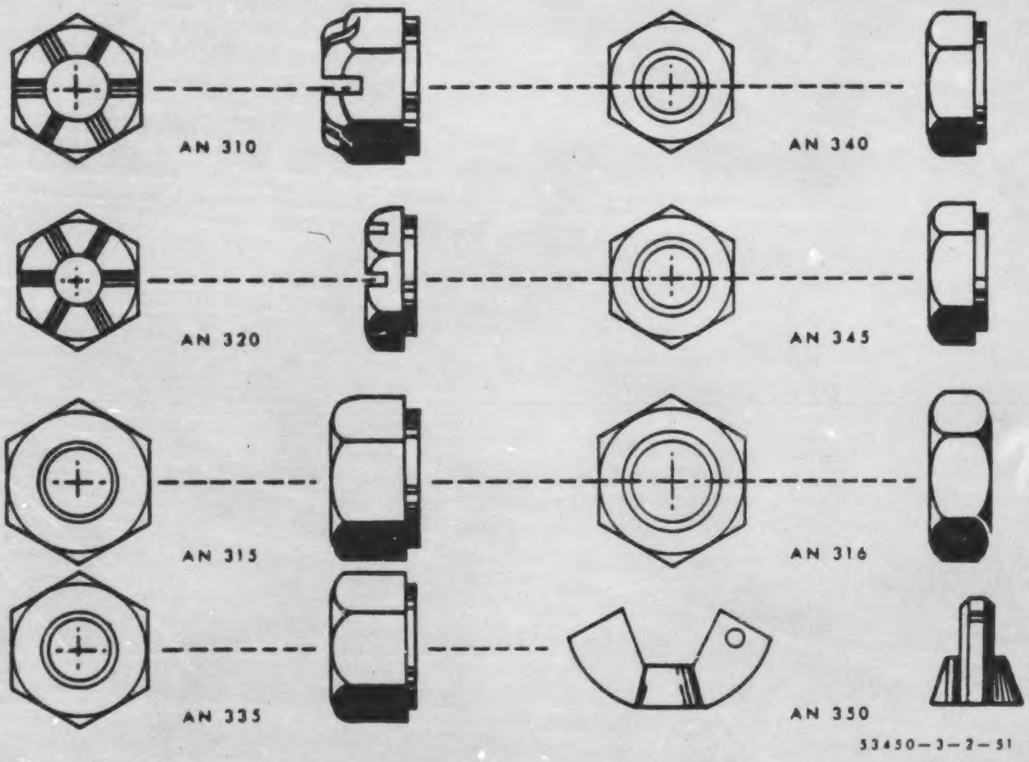


Figure 51. Nonself-locking nuts.

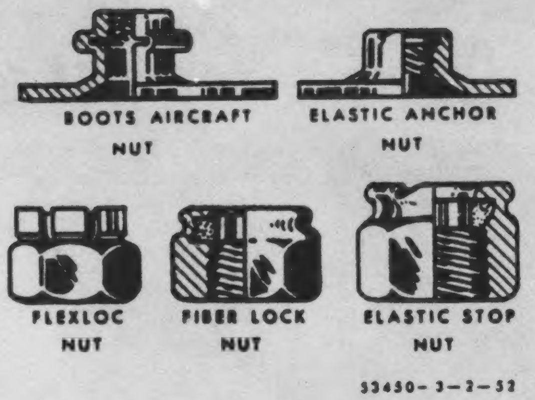


Figure 52. Self-locking nuts.

castellated for safetying. Note, however, that this nut is not as deep or as strong as the castle nut; also that the castellations are not as deep as those in the castle nut.

13-41. The *plain hexnut*, AN315 and AN335 (fine and coarse thread), is of rugged construction. This makes it suitable for carrying large tensional loads. However, since it requires an auxiliary locking device, such as a check nut or lockwasher, its use on aircraft structures is somewhat limited.

13-42. The *light hexnut*, AN340 and AN345 (fine and coarse threads), is a much lighter nut than the plain hex nut and must be locked by an auxiliary device. It is used for miscellaneous light-tension requirements.

13-43. The *plain check nut*, AN316, is employed as a locking device for plain nuts, setscrews, threaded rod ends, and other devices.

13-44. The *wing nut*, AN350, is used where the desired tightness can be obtained with the fingers and where the assembly is frequently removed.

13-45. *Self-locking nuts.* As their name implies, self-locking nuts need no auxiliary means of safetying but have a safetying feature included as an integral part of their construction. They are used in aircraft to provide connections which will not shake loose under severe vibration. So many types of self-locking nuts have been designed that their use has become quite widespread. Common applications are attachment of antifriction bearings and control pulleys, attachment of accessories, as anchor nuts around inspection holes and small tank installation openings, and for attachment of rocker box covers and exhaust stacks.

13-46. The two general types of self-locking nuts currently in use are the all-metal type and the fiber-lock type. For the sake of simplicity, only three typical kinds of self-locking nuts are considered in this CDC: (1) the Boots self-locking; (2) the stainless steel self-locking nuts, representing the all-metal types; and (3) the elastic stop nut, representing the fiber-insert type, illustrated in figure 52.

13-47. The *Boots self-locking nut* is of one-piece all metal construction and holds tight in spite of severe vibration. Note in figure 52 that it has two sections and is essentially two nuts in one—a locking nut and a load-carrying nut. The two sections are connected with a spring which is an integral part of the nut. The spring keeps the locking and load-carrying sections such a distance apart that the two sets of threads are out of phase; that is, so spaced that a bolt which has been screwed through the load-carrying section pushes the locking section outward against the force of the spring to engage the threads of the locking section.

13-48. The spring, through the medium of the locking section, exerts a constant locking force on the bolt in the same direction as a force that tightens the nut. In Boots self-locking nuts, then, the load-carrying section has the thread strength of a standard nut of comparable size; the locking section presses against the threads of the bolt and locks the nut firmly in position. Only a wrench applied to the nut will loosen it. The nut can be removed and reused without impairing its efficiency.

13-49. Boots self-locking nuts are made with three different spring styles and in various shapes and sizes: (1) the wing type, which is the most common, ranges from size number 6 to ¼ inch; (2) the Rol-top ranges from ¼ to $^{5}/_{16}$ inch; and (3) the bellows type ranges from size number 8 to ⅜ inch. Wing nuts are made of anodized aluminum alloy, cadmium-plated carbon steel, or stainless steel. The Rol-top nut is cadmium-plated steel, and the bellows type is made of aluminum alloy only.

13-50. The *stainless steel self-locking nut* may be spun on and off with the fingers, as its locking action takes place only when the nut is seated against a solid surface and tightened. The nut consists of two parts; a case with a beveled locking shoulder and key, and a threaded insert with a locking shoulder and slotted keyway. From the cross-sectional view in figure 53, you can see that the key of the case fits into the slotted keyway of the insert so that when the case is turned the threaded insert is turned with it. Note that the slot is wider than the key. This permits the slot to be narrowed and the insert to be compressed when the nut is tightened.

13-51. Until the nut is tightened, it spins on the bolt easily, because the threaded insert is the proper size for the bolt. However, when the nut is seated against a solid surface and tightened, the locking shoulder of the insert is pulled downward and wedged against the locking shoulder of the

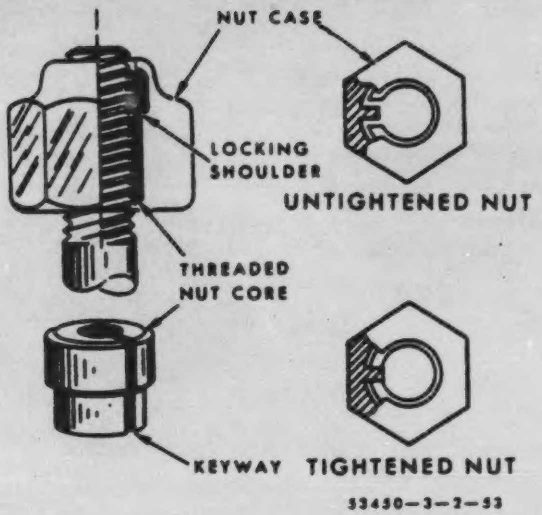


Figure 53. Stainless steel self-locking nuts.

case. This action compresses the threaded insert and causes it to clench the bolt tightly. You can see what has happened by looking at the cross-sectional view of the locked nut in figure 53 and noting how the slotted keyway has been narrowed as a result of the compression of the threaded insert.

13-52. The *elastic stop nut* is a standard nut with the height increased to accommodate a fiber locking collar.

13-53. Note in figure 54 that the fiber locking collar is not threaded and that its inside diameter is smaller than the largest diameter of the threaded portion or the outside diameter of a corresponding bolt. When the nut is screwed onto a bolt, it acts as an ordinary nut until the bolt reaches the fiber collar. When the bolt is screwed into the fiber collar, however, friction (or drag) causes the fiber to be pushed upward. This creates a heavy downward pressure on the load-carrying part and automatically throws the load-carrying sides of the nut and bolt threads into positive contact. After the bolt has been forced all the way through the fiber collar, the downward pressure remains constant. This pressure locks and holds the nut securely in place even under severe vibration.

13-54. Elastic stop nuts range from size number 1 to size number 72 for machine screws, and from ¼ inch to 6 inches for large bolts. All are made with standard type threads. Whatever the shape of the nut, the locking principle is the same.

13-55. *Precautions.* Regardless of the type of nut you are using, always select the correct tool to install it. Socket and box-end wrenches are preferred to open-end wrenches because they do not round the corners of the nut.

13-56. Nearly all elastic stop nuts used by the Air Force are steel or aluminum alloy. However, such nuts are available in practically any kind of metal. Aluminum alloy elastic stop nuts are supplied with an anodized finish. Steel nuts are cadmium plated.

13-57. Normally, you can reuse elastic stop nuts many times with complete safety and without detriment to their locking efficiency, as indicated in the applicable section of TO 1-1A-8. However, you must practice these precautions:

a. Do not use bolts with burrs around cotter pin holes. The rough edges will tear the fiber collar as the bolt passes through it, and this action will eventually reduce the self-locking action. Use bolts without cotter pin holes whenever possible.

b. Do not use sawed-off bolts that have rough ends. If sawed-off bolts are used, file off the burrs before applying the nut.

c. Never tap the fiber collar. The self-locking action of the elastic stop nut is the result of having the bolt threads impress themselves into the untapped fiber.

d. Do not install elastic stop nuts in places where the temperature is higher than 250° F., for the effectiveness of the self-locking action is reduced beyond this point.

e. Always use the proper bolt length. At least ~~one and one-half~~ two threads must extend through the

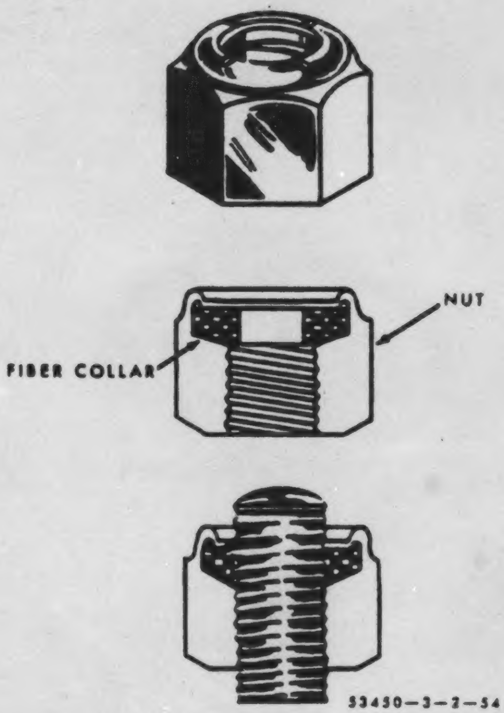


Figure 54. Elastic stop nut.

fiber in order to develop the maximum locking effect.

f. When reusing elastic stop nuts, be sure the fiber has not lost its locking friction or become brittle. If a nut can be turned with the fingers, replace it.

13-58. **Installation of Nuts and Bolts.** Just as the size of the hole for a rivet installation is important, so is the size of the hole important for bolt installation.

13-59. *Bolt and hole sizes.* Slight clearances in bolt holes are permissible wherever bolts are used in tension and are not subject to reversal of load. A few of the applications where clearance of holes is permitted include pulley brackets, conduit boxes, lining trim, and miscellaneous supports and brackets. Light drive fits for bolts (specified on the repair drawings as 0.0015-inch maximum clearance between bolt and hole) are required in places where bolts are used in repair, or where they are placed in the original structure.

13-60. The fit of holes and bolts cannot be defined in terms of shaft and hole diameters; fit is defined in terms of the friction between bolt and hole when the bolt is driven into place. A tight-drive fit, for example, is one in which a sharp blow of a 12- or 14-ounce hammer is required to move the bolt. A bolt that requires a hard blow and sounds tight is considered to fit too tight. A light-drive fit is one in which a bolt will move when you hold a hammer handle against its head and press by the weight of your body. A bolt which moves when pushed with your thumb is considered too loose.

13-61. To obtain a light-drive fit, measure several bolts of the correct nominal size with a micrometer; then separate them into three groups, large, medium, and small. (From the earlier discussion of rivet sizes, remember that the nominal size is the quoted size. A ¼-inch or .250 bolt, for example, may measure only .249 inch instead of .250 inch. The nominal size then would be .250 inch and the actual size .249 inch.) Drill an initial hole approximately 1/32 inch undersize (⅛ inch undersize may be used for larger bolts) and then redrill to 1/64 inch undersize.

13-62. Select a reamer which can cut a hole that will give proper drag when using the smallest bolts. Ream two or three holes and fit the small bolts in the reamed holes. If the hole is too small, make it larger by selecting another reamer of the same nominal size but which will cut a hole slightly larger. If any of these holes is too large for light-drive fit conditions with the small bolts, then the medium or large bolts will probably be just right for a light-drive fit. Drill sizes for bolts are listed in table 10 and may be used when drilling holes for AN bolts.

TABLE 10
AN BOLT DRILL SIZES

BOLT DIAMETER	PILOT HOLE DRILL SIZE	FINAL DRILL OR REAM SIZE
3/16 (10-32)	No. 21 (.159)	No. 11 (.191)
1/4	7/32 (.2187)	1/4 (.250)
5/16	9/32 (.2812)	5/16 (.3125)
3/8	11/32 (.3437)	3/8 (.375)
7/16	13/32 (.4062)	7/16 (.4375)
1/2	15/32 (.4687)	1/2 (.500)
9/16	17/32 (.531)	9/16 (.5625)
5/8	19/32 (.594)	5/8 (.625)
3/4	23/32 (.719)	3/4 (.750)
7/8	27/32 (.844)	7/8 (.875)
1	31/32 (.969)	1 (1.000)

53450.3 2-T12

13-63. Bolt holes must not be oversized or elongated. A bolt in such a hole will carry none of its shear load until parts have yielded or deformed enough to allow the bearing surface of the oversized hole to come in contact with the bolt. In this respect, remember that bolts do not become swaged to fill up the holes as do rivets. Therefore, for oversized or elongated holes, it is permissible to drill or ream the hole to accommodate the next larger bolt, provided the larger hole size does not weaken the part.

13-64. *Torque.* To avoid stripping threads, cracking nuts, or snapping bolts, and to assure that all bolts carry their share of the load, torque all nuts. This means that for every nut you install, you measure the tightening or twisting force or, after much experience, estimate it accurately so that the twisting force will be correct.

13-65. Torque is the product of the applied force and the distance it is applied from the center of the nut. This value may be expressed in pound-inches or in pound-feet; the force is measured in pounds, and the distance from the center of the nut is measured in inches or feet. Thus, a force of 40 pounds applied at the end of a wrench 12 inches long will develop a twisting force of 480 pound-inches. If 40 pounds of force were applied at the end of a 3-foot bar and wrench, a twisting force of 120 pound-feet would be developed. (This value could also be given as 1440 pound-inches.)

13-66. Nuts which are tightened without a torque wrench are seldom drawn up to the correct tightness. They are either overtightened because of the variables involved or they are undertorqued because of unsuspected friction. Such guesswork may result in aircraft failure. Tables for the torquing of bolts have not been set up for aircraft use, but tables to be used when torquing nuts have been established. Use these torque tables in applying nuts. Follow the instructions in the erection and maintenance instruction manuals for specific aircraft.

13-67. **Washers.** Washers used in airframe repair are either plain washers, lock washers, or special type washers.

13-68. *Plain washers.* Plain washers, shown in figure 55, both the AN960 and AN970, are used under AN hex nuts. They provide a smooth bearing surface and act as a shim to obtain correct grip length for a bolt and nut assembly. They are used to adjust the position of castellated nuts in respect to drilled cotter pin holes in bolts. Plain washers are used under lock washers to prevent damage to the surface material.

13-69. Aluminum and aluminum alloy washers are used under bolt heads or nuts on aluminum alloy or magnesium structures where corrosion caused by dissimilar metals is a factor. Then any electrical current flow will be between the washer and the steel bolt. However, it is common practice to use a cadmium-plated steel washer under a nut bearing directly against a structure. This washer will resist the cutting action of a nut better than an aluminum alloy washer.

13-70. The AN970 steel washer has a greater bearing area than the AN960 washer. It is used on wooden structures under both the head of a bolt and the nut to prevent crushing the surface.

13-71. *Lock washers.* Lock washers, both the AN935 and AN936, are used with machine screws or bolts where the self-locking or castellated type nut is not appropriate. The spring action of the washer provides enough friction to prevent loosening of the nut from vibration (see fig. 55).

13-72. Lock washers are not used under the following conditions:

- As fastenings to primary or secondary structures.
- As fastenings on any part of the aircraft where failure might result in damage or danger to the aircraft or personnel.
- Where failure would permit the opening of a joint to the airflow.
- Where the screw is subject to frequent removal.
- Where the washers are exposed to the airflow.
- Where the washers are subject to corrosive conditions.
- Where the washer is against soft material without a plain washer underneath to prevent gouging the surface.

13-73. *Special washers.* The ball-socket and seat washers, AC950 and AC955, are special washers used where a bolt is installed at an angle

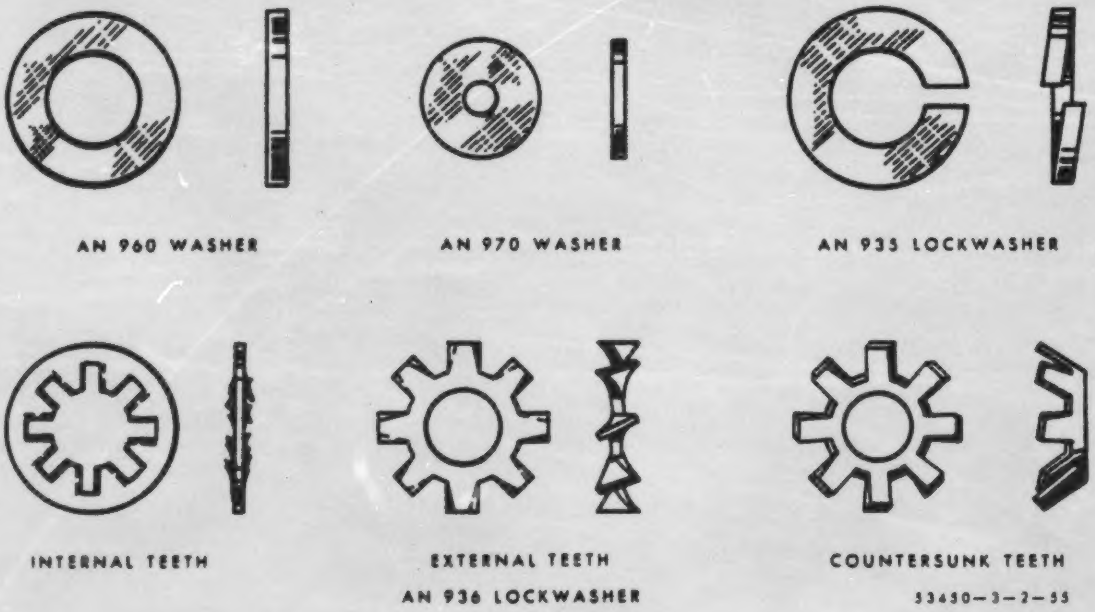


Figure 55. Plain and lock type washers.

to a surface, or where perfect alignment with a surface is required. These washers are used together. They are shown in figure 56.

13-74. The NAS143 is a washer used with internal wrenching bolts of the NAS144 through NAS158 series. This washer is either plain or countersunk. The countersunk washer is used to seat the bolt head shank radius, and the plain washer is used under the nut.

13-75. **Aircraft Screws.** Screws are among the most commonly used threaded fastening devices used on aircraft. They are generally made of lower strength materials than are used for bolts. They can be installed with a loose-fitting thread, and the head shapes are made to engage a screwdriver or wrench. Some screws have no clearly defined grip or unthreaded portion while others are threaded along their entire length.

13-76. Several types of structural screws differ from the standard structural bolts only in head style. The material in them is the same and a definite grip length is provided. The AN525 washer head screw and the NAS220 through NAS227 series are such screws.

13-77. Screws are classified in three groups: (1) structural screws, which have the same strength as equal size bolts; (2) machine screws, which include the majority of types used for general repair; and (3) self-tapping screws, which are used for attaching lighter parts.

13-78. *Identification and coding.* The coding system used to identify screws is similar to the one used for bolts. There are AN and NAS screws. NAS screws are structural screws. Part numbers 510, 515, 550, and so on, catalog screws into classes, such as roundhead, flathead, washer head, and so on. Letters and digits indicate the material composition, length and thickness. Figure 57 explains the coding system used to identify screws.

13-79. *Structural screws.* Structural screws are made of alloy steel, are properly heat treated, and can also be used as structural bolts. These screws are manufactured in the NAS220 through NAS227 and AN509 and AN525 series. They have a definite grip and the same shear strength as a bolt the same size. Shank tolerances are similar to AN hex head bolts, and the threads are National Fine. Structural screws are available with round, brazier, or countersunk heads. Use either a Phillips or a Reed and Prince screwdriver to install recessed head screws.

13-80. The AN509 (100°) flathead screw is used in countersunk holes where a flush surface is necessary.

13-81. The AN525 washer-head structural screw is used where raised heads are not objectionable. The washer-head screw provides a large contact area.

13-82. *Machine screws.* Machine screws are usually of the flathead (countersunk), roundhead, or washer-head types. These screws are general

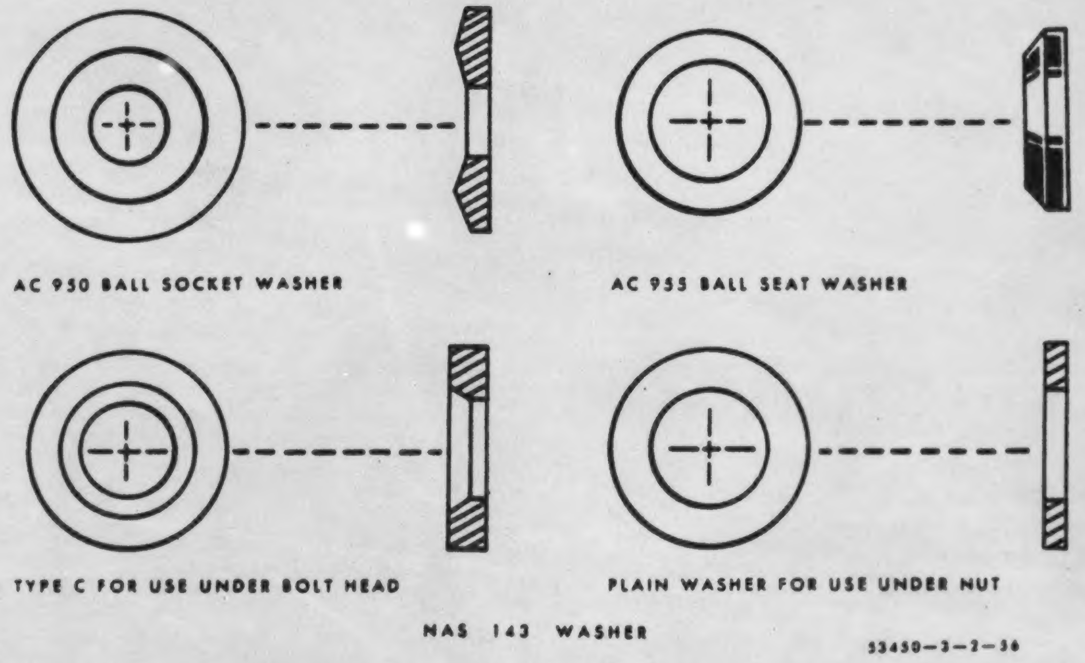

AC 950 BALL SOCKET WASHER
AC 955 BALL SEAT WASHER
TYPE C FOR USE UNDER BOLT HEAD
PLAIN WASHER FOR USE UNDER NUT
NAS 143 WASHER
53450—3—2—36

Figure 56. Special washers.

AN500—6—7

AN = AIR FORCE - NAVY STANDARD
500 = FILLISTER-HEAD SCREW, COARSE THREAD
6 = DIAMETER SIZE — NUMBER 6
7 = LENGTH IN 16THS OF AN INCH

AN501B—416—7

AN = AIR FORCE - NAVY STANDARD
501 = FILLISTER-HEAD, FINE THREAD
B = BRASS
416 = 4/16-INCH DIAMETER
7 = 7/16-INCH LENGTH

THE LETTER 'D' IN PLACE OF THE 'B' WOULD INDICATE THAT THE MATERIAL IS 2017T ALUMINUM ALLOY. THE LETTER 'C' WOULD DESIGNATE CORROSION RESISTING STEEL.

AN 'A' PLACED BEFORE THE MATERIAL CODE LETTER WOULD INDICATE THAT THE HEAD IS DRILLED FOR SAFETYING.

NOW LET US EXAMINE A CODE NUMBER FOR AN 'NAS' SCREW

NAS228DD—8

NAS = NATIONAL AIRCRAFT STANDARD
228 = HEAD STYLE AND RECESS — BRAZIER HEAD RECESSED FOR A 'REED AND PRINCE' SCREWDRIVER.
DD = 2024T ALUMINUM ALLOY — ABSENCE OF A LETTER INDICATES ALLOY STEEL
8 = SCREW LENGTH IN 16THS OF AN INCH

53430—3—2—57

Figure 57. Screw numbering system.

purpose screws and are available in low-carbon steel, brass, corrosion-resistant steel, and aluminum alloy.

13-83. Roundhead screws, AN515 and AN520, have either slotted or recessed heads. The AN515 screw has coarse threads and the AN520 has fine threads.

13-84. Countersunk machine screws are listed as AN505 and AN510 for 82°, and AN507 for 100°. The AN505 and AN510 correspond to the AN515 and AN520 roundhead in material and usage.

13-85. The filister-head screw, AN500 through AN503, is a general-purpose screw and is used as a capscrew in light mechanisms. This could include attachments of cast aluminum parts, such as gearbox cover plates.

13-86. The AN500 and AN501 are available in low-carbon steel, corrosion-resistant steel, and brass. The AN500 has coarse threads; the AN 501 has fine threads. These screws have no clearly defined grip length. The screws that are larger than number 6 have a hole drilled through the head for safetying purposes.

13-87. The AN502 and AN503 filister-head screws are made of heat-treated alloy steel, have a small grip, and are available in fine and coarse threads. These screws are used as capscrews where great strength is required. The coarse-threaded screws are commonly used as cap screws in tapped aluminum alloy and magnesium castings because of the softness of the metal.

13-88. *Self-tapping screws.* Machine self-tapping screws are listed as AN504 and AN506. The AN504 screw is roundhead, and the AN506 is 82° countersunk. These screws are used for attaching removable parts, such as nameplates, to castings and parts in which the screw cuts its own threads after the part has been underdrilled.

13-89. AN530 and AN531 sheet metal screws, like the Parker-Kalon Z type sheet metal screw, are blunt on the end. They are used in the temporary attachment of sheet metal for riveting, and in the permanent assembly of nonstructural assemblies.

NOTE: Self-tapping screws should not be used to replace standard screws, nuts, bolts, or rivets in the original structure.

13-90. **Resistance Welding.** While resistance welding is not a fastening device as such, it is a way of fastening materials. Electric resistance welding is easier, cleaner, quieter, and quicker than standard fastening procedures. The heat can be localized at the exact spot where the weld (or fusion) is desired. The amount of heat and the extent of fusion can be controlled. Also no addition of filler metal to the weld is required. These welds are made on a production basis and no material is lost. Pieces with difficult physical shapes and different physical characteristics can be resistance welded.

13-91. The combining of two pieces of metal without loss of strength is the prime object of all welding. This means that all good welds are even stronger than the pieces joined. In airframe repair, spot heating of the metals to be joined through the use of electrodes has proved valuable.

13-92. Spot-welding is the most widely used resistance welding process. The name "spot weld" stems from the fact that the weld is made at one particular point or spot between the electrodes. Spot-welding machines are made in a variety of types and sizes but are usually classed as either rocker-arm or press type.

13-93. The rocker-arm welder, illustrated in figure 58, has a movable upper arm which lowers and rises in a vertical arc when it is in operation. The rocker arm is actuated by air. The average rocker-arm spot welder uses a 90-psi air line pressure. The air operating the arm is expelled as the arm returns to the normal raised position. This machine is used primarily in welding lightgage metals, but is it also used successfully for heavier materials.

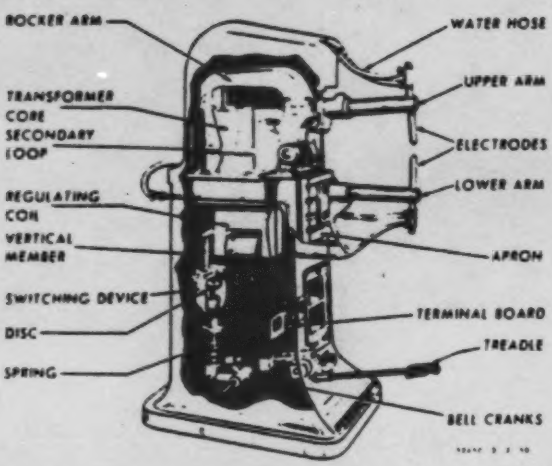


Figure 58. **Resistance welder.**

13-94. The press type spot welder has a straight up and down movement of the upper arm similar to that of a punch press. It is used for welding metals that require high secondary current and forging force. In addition to this machine, there are multiple spot welders that make several spot welds at one movement of the upper arm.

13-95. Portable gun welders are used on parts and assemblies that do not fit into the throat of conventional machines. The control panel and transformer of portable machines may be suspended from overhead rails and moved freely about the work area. They also are mounted on portable carts and are rolled to the area where needed. This welder has only one electrode on the gun.

13-96. The seam welder produces welds similar to spot welds. The primary difference between this welder and those previously discussed is in the electrodes, which are wheels or rollers made of copper alloy. The work is placed between the wheels and pressure is applied to hold the parts in close contact. One of the wheels is motor driven at an adjustable speed. The speed at which the work is moved and the length of time the current flows may be regulated to produce either overlapping welds or spots spaced an inch or two apart. The overlapping welds result in a continuous seam which makes the work gas-tight. This machine is used in manufacturing jet engine inner and outer combustion chambers and tail cone assemblies.

13-97. Begin the electrode dressing procedure by inserting a mill file between the electrode tips. Turn the air adjustment screw counterclockwise and trip the foot pedal to release the air pressure and allow the points to come together. Mill the points by rotating the file back and forth horizontally until the desired diameter is obtained. Apply air pressure by turning the air regulator dial clockwise to release the points. File a slight dome on the points and finish with emery cloth.

13-98. With continual passing of water through the copper lines into the electrodes, a certain amount of deposit and corrosion build up. Clean the lines and the inside of the electrodes every week or 10 days. Flush the line out before connecting it back to the machine.

13-99. *Spot weld inspection, testing, and repair.* The outer surface of a good spot weld is smooth, free of cracks and pits, and free of pickup from the tips. Internal inspection of a weld is made by lapping two specimens of metal together, welding, and then shearing through the weld. The sheared weld should present a round, fine-grained, rough-fused area. The rough weld area is proof that a good bond has been obtained and that the metal from one specimen is fused into the other.

13-100. After a weld passes visual inspection, two samples of the materials are lapped and welded for a tensile test.

13-101. Sometimes there is a spotweld failure and the skin separates from the structure leaving a button or part of a button. First use a counterbore to mill off the button. Then, to drill out the spot weld, use a drill the same size as that used to drill rivet holes for that particular skin thickness. Since drilling does not completely remove the spot weld, use a chisel between the sheets to break them apart.

13-102. Prepare a spacer of the same gage as the skin and install it in the hole that you drilled out. Make a washer at least six diameters larger than the rivet size and bevel the edges of the washer. Drill the hole in the washer, insert the rivet, and drive the rivet. Use normal procedures to drive the rivet.

CHAPTER 4

Structural Repair

IN AVIATION's early days, wooden aircraft structures, reinforced by metal accessories, were strong enough to withstand the vibrations and torsional stresses occurring in slow-flying aircraft. Highly skilled woodcraftsmen maintained the wooden parts. Little metal repair was needed.

2. As aircraft speed and engine power increased, wood became unsatisfactory. Engineers and manufacturers realized that structural parts made from metal would have to replace wood, so they developed strong light weight metal alloys. Structural forming and reinforcement methods were applied to save more weight and provide the strength required for high-speed flight and maneuvers.

3. The shift from wood to metal required a corresponding change to train maintenance personnel in metalworking instead of woodworking. Instead of having to know such details as the grain, strength, and weight of various woods, the repairman needed to know the characteristics of metals.

4. Unlike the woodcraftsman's knowledge, the airframe repairman's knowledge does not stop with metals and metal-working principles. In this age of high-speed aircraft, he must understand the principles of streamlining and fairing, aerodynamics, the behavior of various metals in high-velocity air currents, and the torsional stresses encountered during high-speed flying and maneuvering. In brief, he has to think of the aircraft in terms of high-speed performance.

5. Application of these principles involves selecting the kind of metal for structural strength and streamlining, the style of rivet to use, and the type of patch that will retain correct contour; determining how much weight can be added and still be within safe limits; and choosing the methods of structural forming and reinforcement to use. With the development of newer, lighter, and stronger alloys, the airframe repairman must keep abreast of such development, not only in maintenance, but in aviation generally.

6. This chapter begins by reviewing aircraft structures and the fundamentals of flight aerodynamics. The chapter continues with a discussion of principles of structural repair; both general and specific structural repair are discussed. Structural sealing and aerodynamic smoothing are also explained. The chapter concludes with a presentation of material on fuel tank repair. This information will help you repair aircraft structures in an efficient manner. When you complete your study of this chapter, you should be able to classify and evaluate damage to structures and parts, determine repair requirements, fabricate the repair, and inspect the completed work.

14. Principal Structural Units

14-1. An aircraft is constructed of many parts which are either riveted, bolted, screwed, or welded together. Since these parts make up the structure of the aircraft, they are called structural members. Many of these members are grouped into several units or assemblies. The fuselage, the wings, the stabilizers, the flight-control surfaces, the nacelles, and the landing gear are the principal structural units of an aircraft. The combined units are called the aircraft structure, or the airframe, and the repair and maintenance of the structural members is called airframe maintenance or repair. A clear understanding of the location, construction, and purpose of the various structural units of the aircraft is necessary for an intelligent approach to the problems of airframe repair.

14-2. **Fuselage.** The fuselage is the main structural unit of the aircraft. Other structural units are directly or indirectly attached to the fuselage. From the standpoint of outline and general design, the fuselage of one type of aircraft is much the same as any other. Many different designs have been successfully tried for the many different USAF requirements and the most satisfactory features are still incorporated in the latest aircraft. Fuselage designs vary principally in size and arrangement of the different compartments.

14-3. On military single-engine aircraft, the fuselage houses the powerplant, the personnel, and the cargo. On most multiengine aircraft, the pow-

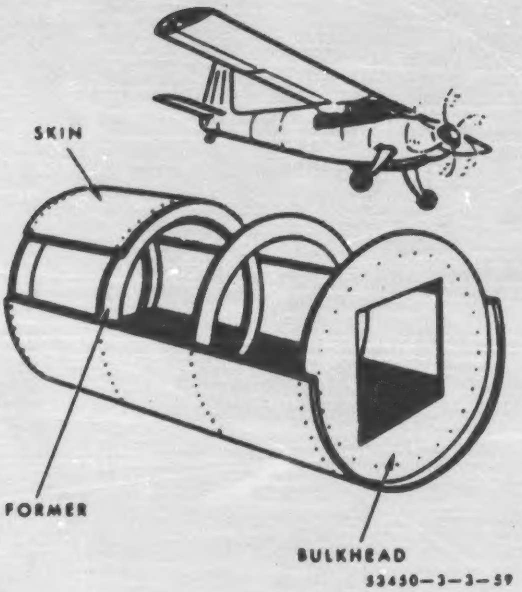


Figure 59. Monocoque construction.

erplants are either housed in compartments called nacelles, which are built into the wings, or the powerplants are suspended in pods from the wings. Aircraft with booms are the exception. The detail of fuselage design varies with the manufacturer of the aircraft and with the requirements of the service for which the aircraft is intended. In style, strength, and construction, aircraft range from slow, light, liaison types to the speedy fighters and bombers.

14-4. *Construction.* The two basic types of fuselage construction are the truss and the monocoque. The truss type is a rigid framework made up of members such as beams, struts and bars. It resists deformation by applied loads. The monocoque type is constructed like a shell. The skin of the fuselage bears the primary stresses. The strength of construction necessary depends upon the power used, speed, maneuverability, and design. The fabric-covered truss-framed fuselage is built for low power rating, slow speeds, and light construction. The truss type is used on many liaison aircraft and on small, light private aircraft.

14-5. The true monocoque type of construction is seldom used because the skin acts as the principal part of the airframe. Formers, frame assemblies, and bulkheads are used to give the shape, but the skin carries the primary stresses. Since no bracing members are present, the skin must be strong enough to keep the fuselage rigid. One of the big problems involved in monocoque construction is maintaining enough strength, yet keeping the weight within the allowable limits. Notice these features in the illustration in figure 59.

14-6. To overcome the strength-weight problem of monocoque construction a modification of it, called *semimonocoque*, was developed. This is used in the construction of nearly all presentday military aircraft.

14-7. *Structural members.* Bulkheads, frame assemblies, and formers serve the dual purpose of giving cross-sectional shape to the fuselage and of adding rigidity and strength to the structure. The shape and size of these members vary considerably, depending on their function and position in the fuselage. Formers are the lightest and are used primarily for fillings or skin attachments between the larger members. Frame assemblies are the most numerous and outstanding members in the fuselage both from the standpoint of appearance and as strengthening devices. Whenever frame assemblies are used to separate one area from another, they become circular discs, reinforced, and equipped with doors or other means of access, and are called *bulkheads.*

14-8. Channel members, hat sections, and built-up assemblies are inserted to provide additional strength. Station webs are built-up assem-

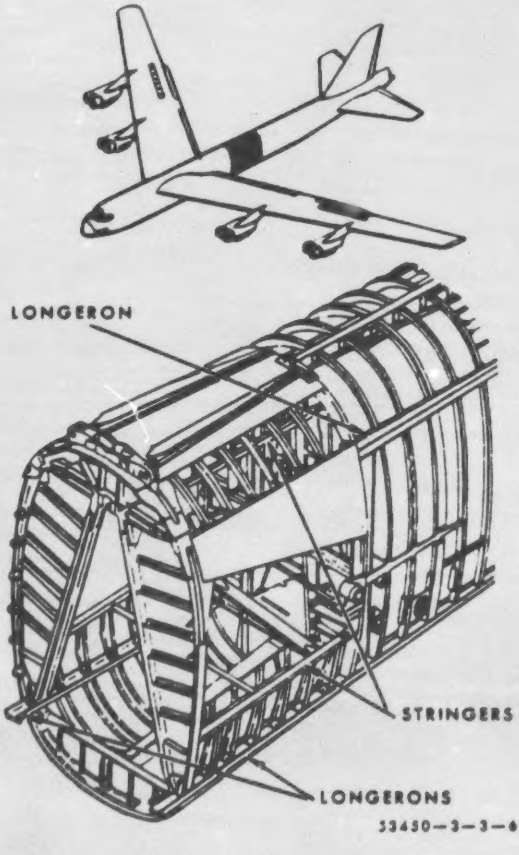


Figure 60. Longerons and stringers.

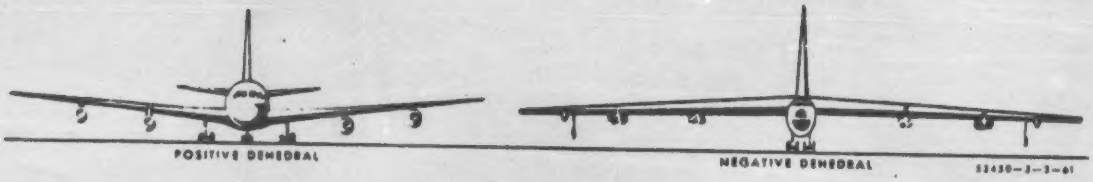


Figure 61. Wing design.

blies located at various points for the attachment of fittings or external parts such as empennage surface fittings, engine mounts, wing attachments, and landing gears.

14-9. Stringers and longerons are the main lengthwise members of the fuselage structures. In figure 60 note that the longeron is a fairly heavy member. Several of these usually run the whole length of the fuselage.

14-10. In figure 60, notice the stringers are smaller and lighter and serve as fill-ins. They have some rigidity but are chiefly used for giving shape and for attachment of the skin. Longerons are stronger and heavier than stringers. The longerons hold the bulkheads and formers, and these, in turn, hold the stringers. All of these joined together form a rigid fuselage framework. Stringers and longerons may be formed angles, channels, hat sections, or extrusions. Angles and channels are formed (folded or bent) into angular longitudinal forms. The angular shape adds to the rigidity of the structure.

14-11. **Nacelle.** Nacelles are streamlined structural units used on multiengine aircraft primarily to house the engines. Here again we find that the design varies depending partly on the manufacturer and partly on the use for which the nacelle is intended.

14-12. *Construction.* On aircraft having double fuselages called booms, the engines are built into the front ends of the booms where they attach to the wings. The nacelle rests on the center wing panel and houses the personnel, the controls, and cargo.

14-13. On twin-engine aircraft, the nacelles also house the main landing gear and related equipment. On four-engine aircraft, the main landing gear is enclosed in the inboard nacelles.

14-14. *Repair.* Whether the nacelle houses a piston engine, a jet engine, landing gear, cargo, or personnel, the fundamentals of repair are esssentially the same as for the fuselage. There must be sufficient strength, whether truss, monocoque, or semimonocoque. The weight must be kept to a minimum, and the exterior must be aerodynamically suited for the nacelle's place on the aircraft.

14-15. Airframe maintenance on the nacelle involves skin, formers, bulkheads, rings, longerons, and so forth, as in the fuselage. Repair is intended to restore the part so that it will serve its original purpose.

14-16. **Wings.** The wings of an aircraft are surfaces designed to give lifting force when moved rapidly through the air. The particular wing design for any given aircraft depends on a number of factors—such as size, weight, use of the aircraft, desired speed in flight and at landing, and desired rate of climb. The wings are designated as left and right, corresponding to the left and right hands of the pilot seated in the cockpit or the pilot's compartment.

14-17. *Design.* The wings of military aircraft are usually of cantilever design; that is, they are built so that no external bracing is needed. With few exceptions, wings of this design are of the stressed skin type, which means that the skin is part of the wing structure and carries part of the wing stresses.

14-18. In general, wing construction is based on one of three fundamental designs—monospar (one), multispar (two or more), and box beam. Slight modifications of these basic designs may be adopted by various manufacturers.

14-19. The monospar wing incorporates only one main longitudinal member (spar) in its construction. Ribs or bulkheads supply the necessary contour or shape to the airfoil. Although the strict monospar type wing is not common, this type of design, modified by the addition of false spars or light shear webs along the trailing edge as support for the control surfaces, is often used.

14-20. The multispar wing incorporates more than one main longitudinal member (spar) in its construction. To give the wing contour, ribs or bulkheads are often included. This type of construction, or some modification of it, is used in the lighter types of combat aircraft.

14-21. The box-beam type of wing construction uses two main longitudinal members with connecting bulkheads to furnish additional strength and to give contour to the wing. A corrugated sheet may be placed between the bulkheads and the smooth outer skin so that the wing can better carry tension and compression loads. In some cases, heavy longitudinal stiffeners are substituted for the corrugated sheets. A combination of corrugated sheets

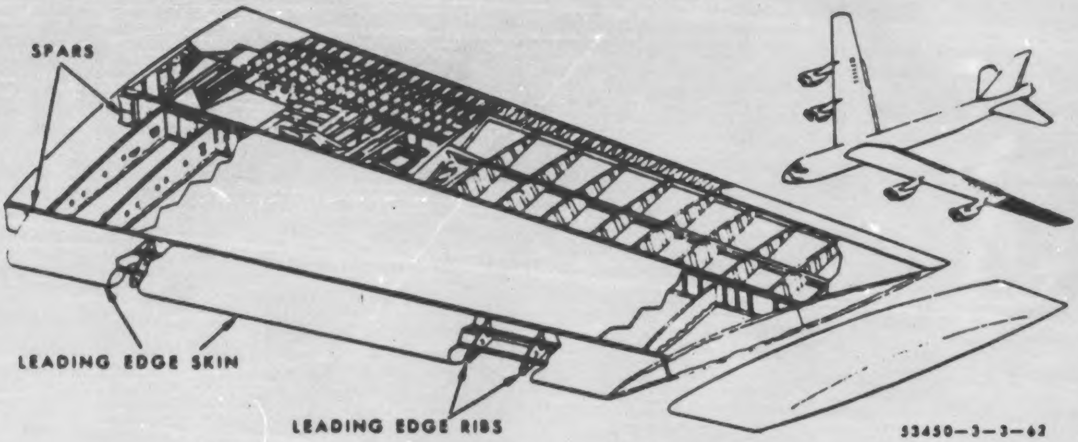


Figure 62. Interior wing construction.

on the upper surface of the wing and stiffeners on the lower surface is sometimes used.

14-22. Other variations in wing design are necessary because of the angle at which the wing attaches to the fuselage. Wings angled upward have positive dihedral; wings angled downward have negative dihedral and are illustrated in figure 61.

14-23. Features of the wing will cause other variations in its design. The wingtip may be square, rounded, or even pointed. Both the leading edge and the trailing edge of the wing may be straight or curved, or one edge may be straight and the other curved. In addition, one or both edges may be tapered so that the wing is narrower at the tip than at the root where it joins the fuselage. Numerous types of modern aircraft use sweptback wings.

14-24. *Internal construction.* The main structural parts of a wing are the spars, the ribs or bulkheads, and the stringers or stiffeners, illustrated in figure 62. These structural parts are riveted or welded together.

14-25. Spars are the principal structural members of the wing. They correspond to the longerons of the fuselage. They run parallel to the lateral axis, or toward the tip of the wing, and are usually attached to the fuselage by wing fittings, plain beams, or part of a truss system.

14-26. The I-beam type of construction for a spar consists of a web (the deep wall plate) and cap strips (which in reality are extrusions or formed angles). The web forms the principal depth portion of the spar. Cap strips are extrusions, formed angles, or milled sections to which the web is attached. These carry the loads caused by the wing bending, and also provide a foundation for attaching the skin. Stiffeners give additional strength to the spar structure. Stiffeners may be beads pressed into the web, or extrusions or formed angles riveted to the web either vertically or diagonally.

14-27. Ribs are the crosspieces that make up the framework of a wing. They run from the leading edge toward the trailing edge (front to rear) of the wing. The ribs give the wing its form and transmit the load from the skin to the spars.

14-28. Ribs are also used in ailerons, elevators, fins, and stabilizers.

14-29. One type of rib is the formed rib, made from a single piece of metal, with the flanges and beads formed in one operation. An example is seen in figure 62.

14-30. Another type of rib is made of a stamped web with cap strips of extrusions or formed angles riveted to the top and bottom edges. In some cases, the rib is made from a channel extrusion reinforced with tubular diagonal and vertical members.

14-31. *Skin.* The smooth outer cover of an aircraft is referred to as its skin. The skin covers the main structural units—wings, nacelles, fuselage, and control surfaces.

14-32. The material used for the skin covering is usually sheet aluminum alloy, treated so that it will not corrode. Tapered and preformed aluminum may also be used. Magnesium and stainless steel are used, but only to a limited extent.

14-33. The thickness of the skin materials covering a structural unit may differ depending on the load and stresses imposed within and throughout the structure. These thicknesses are determined by the manufacturer and must be matched with material of the specified thickness during repair work performed by the airframe repairman.

14-34. *Fairing.* To prevent turbulence in the airflow, or to smooth out the airflow over the angles formed by the wings and other structural units with the fuselage, shaped and rounded sheet stock called fairing is used. The cowling of all engines, whether housed in the fuselage or in nacelles, is streamlined to prevent air turbulence and reduce drag; it may also be considered fairing. The fairing used around the wings or tail surfaces is often called fillets, and expressions such as wing fillets and rudder fillets are common and correct.

14-35. **Empennage.** The empennage is simply the tail section of the aircraft. It includes the aft end of the fuselage or booms, the rudder or rudders, elevators, and stabilizers.

14-36. The stabilizing units of an aircraft consist of vertical and horizontal surfaces located on the rear portion of the fuselage. They are parts of the empennage or tail assembly. The vertical surface is called the vertical stabilizer, or fin, and the horizontal surface is referred to as the horizontal stabilizer.

14-37. The vertical stabilizer, or fin, serves to maintain directional stability of the aircraft in flight about its vertical axis. On single-engine propeller-driven aircraft, the fin is sometimes off-set in relation to the fuselage to furnish directional balance by compensating for the torque or twist caused by the engine. The fin is also the base or anchorage for attaching the rudder.

14-38. Stability about the lateral axis of the aircraft is given by the horizontal stabilizer, which serves also as a base or anchorage for attaching the elevators.

14-39. As with the wings, there are many variations to be found in the size, shape, and placement relative to the fuselage, as well as in the number of component parts comprising the empennage.

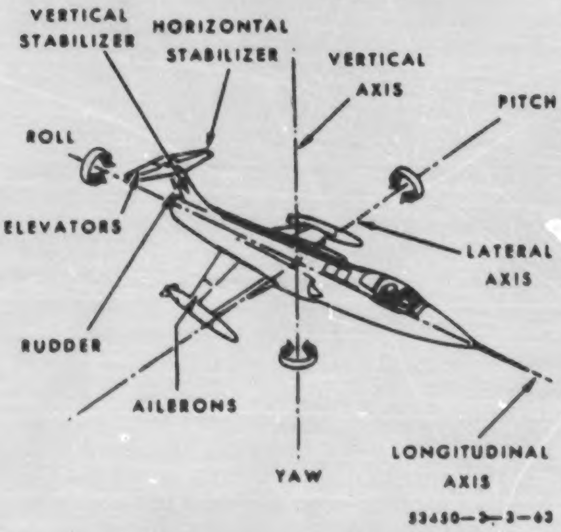


Figure 63. Axis and fundamental motions.

14-40. **Flight Control Surfaces.** You are familiar with the simple processes involved in changing the direction of a moving vehicle such as a truck, bus, or automobile. A mere turn of the front wheels does the job. In contrast to this directional change in one lateral plane of movement, an aircraft is unrestricted. The directional control of an aircraft takes place around all three axes—the lateral, the longitudinal, and the vertical—and is illustrated in figure 63.

14-41. Flight control surfaces are hinged or movable surfaces which control the attitude or maneuvers of an aircraft during takeoff, flight, and landing. They consist of two major groups: the main, or primary, and the auxiliary.

14-42. *Main group.* The main group of flight control surfaces consists of ailerons, elevators, and rudders. The ailerons are attached to the trailing edge of the wing sections of both the right and left wings of the aircraft. The elevators are attached to the trailing edge portion of the horizontal stabilizer. The rudder is attached to the trailing edge portion of the vertical stablizer.

14-43. All the various units of the main group are similar in construction and vary only in size, shape, and in minor differences in attachments. In turn, the construction of these units is similar to that of the all-metal wing.

14-44. Main control surfaces are movable surfaces and are usually made of an aluminum alloy structure built around a single spar member or torque tube. Ribs are fitted to the spar at the leading and trailing edges and are joined together with a metal strip. The ribs, in most cases, are formed from flat sheet stock. They are not solid, but contain punched holes which save weight. The trailing edges are made in various shapes and sizes.

14-45. *Auxiliary group.* The auxiliary group of control surfaces is composed of trim tabs, balance tabs, servo tabs, and flaps. Their purpose is to reduce the force required to actuate the main group, to trim and balance the aircraft in flight, to reduce landing speed or shorten the length of the landing roll, and to change the speed of the aircraft in flight. They are attached to the trailing edges or recessed into the main control surfaces.

14-46. Trim tabs are used to control the balance of the aircraft so that it will maintain level flight without pressure on the control stick or rudder pedals. They are of two types: ground-adjustable and flight-adjustable. The ground-adjustable trim tab is usually a narrow strip of aluminum alloy attached to the trailing edge of one of the main control surfaces and, as its name implies, is adjusted only when the aircraft is on the ground. It is labeled "hands off" because any slight change in its adjustment will alter the action of the aircraft during flight. This type is usually found on training and liaison aircraft but seldom on combat aircraft.

14-47. The flight-adjustable trim tab is recessed into the trailing edge of one of the main control surfaces of the aircraft. It is controlled by linkage from the cockpit and is adjusted at will during flight.

14-48. The trim tab remains in the same position in relation to the main control surface, no matter in what position the main surface is placed.

14-49. Balance tabs are hinged to the main control surfaces and are connected to the fixed structure by mechanical linkage to cause the tab to move in a direction opposite to that of the main control surface. Balance tabs reduce the effort required by the pilot to move or to hold the control surface in any given position. The linkage between the tab and the wing structure is often adjustable—making a tab a ground-adjustable balance tab.

14-50. Servo tabs are used primarily on large airfoils to aid the pilot in moving primary control surfaces. The tab control linkage is connected in such a manner that tab movement precedes the movement of the main control surface. Air from the slipstream striking the tab will move the control surface in the desired direction.

14-51. Flaps increase lift and drag of the wing. They enable fast aircraft to reduce landing and takeoff speed. This shortens the landing roll in small or obstructed areas by permitting the gliding angle to be increased without increasing the gliding speed. As a rule, flaps are located on the surface of the rear portion of the wing from the aileron inward to the fuselage. Flaps are operated hydraulically or electrically.

14-52. The ailerons, elevators, and rudder are the surfaces by which maneuvers such as right and left bank, right and left turn, and nose-up and nose-down are made. Very few maneuvers or turns are executed by using only one of the three.

14-53. A right turn, for instance, requires the left aileron to be turned down, which action pushes the left wing up; the right aileron to be turned up, which action pushes the right wing down; and the rudder to be turned to the right, which action moves the tail end of the fuselage to the left. At the same time, the elevators must be raised slightly so that the tail end of the fuselage is pushed down. This action raises the nose to compensate for a possible loss of altitude while the pilot is making the turn.

14-54. On several of the latest series aircraft, some of the control surfaces serve a dual purpose. For example, on the F-102 elevons are control surfaces which combine the functions of the ailerons and elevators, hence the name. Flaperons are ailerons which act also as flaps. A movable horizontal tail is a control surface which supplies the action of both the horizontal stabilizer and the elevator.

14-55. A spoiler is a small, narrow, hinged, striplike flap arranged to project above the upper forward surface of a wing, ahead of the ailerons. Its purpose is to disturb the smooth airflow and increase the drag on a wingtip at the same time that the aileron on the same wing is turned upward. It makes an upturned aileron more effective. In some experimental cases, spoilers have been used in place of ailerons.

14-56. Wing slats are airfoils attached to the leading edge of each wing panel. Slats reduce burbling and smooth out the flow of air over the airfoil. On most aircraft equipped with slats, aerodynamic forces acting upon the slats cause them to open or close automatically, depending on the airspeed and attitude of the aircraft. The automatic extension of the slats changes the airflow over the upper surface of the wing, increasing the lift and thus producing a lower stalling speed.

15. Aerodynamic Factors

15-1. As an airframe repairman, you repair, fabricate, and modify aircraft structures. Although basic flight theory and aerodynamics were considered in full detail when the aircraft was designed, you should know this information and consider how a repair might be affected by these factors.

15-2. It will be necessary for you to repair the exterior surfaces of aircraft. Some of these are critical aerodynamic surfaces. They must be repaired so that the air will pass over them as smoothly as possible. Wing leading edges, wing upper and lower surfaces, and control surfaces are some of the more important areas which must be aerodynamically smooth.

15-3. You must make repairs that *are not only* structurally sound but also aerodynamically smooth. An understanding of the design and purpose of aircraft structures, along with the theory of flight principles, is important. The smoothness of repairs to these surfaces is limited by the repairman's capability.

15-4. **Aerodynamic Forces.** Our purpose here is to consider the forces which contribute to aircraft lift and control. Four forces affect the aircraft in flight: gravity, thrust, drag, and lift. Now let us review how they act on an aircraft.

15-5. *Gravity.* Gravity is the force which tends to draw an object toward the earth or hold it on the earth. To leave the ground and remain in flight, the aircraft must overcome the pull of gravity. A parked aircraft has only the force of gravity working upon it. Suppose, however, that this aircraft is at the end of a runway ready for takeoff. The next force it will need is thrust.

15-6. *Thrust.* Thrust is the forward force produced by the engine through the propeller or, in jet engines, by the reaction to movement of mass (air and exhaust gases). In the study of thrust, one becomes involved with drag and inertia.

15-7. *Drag.* Inertia is that property of matter which causes an object to remain stationary or in uniform motion in a straight line until compelled to change direction by a force acting upon it. In other words, if the aircraft is set in motion by applying the force of thrust, it will remain in motion, in a straight line, until a force is applied to stop it. This stopping force is present in the resistance of the air itself to an aircraft passing through it. This resistance of the air represents a force which is called a drag.

15-8. Thrust, then, is the force which sets an aircraft in motion and keeps it in motion against the force of drag. Thrust can overcome the inertia of an aircraft to get it moving and can overcome the force of drag to keep it moving.

15-9. *Lift.* If the forces of gravity, thrust, and drag were the only ones acting on the aircraft, it would move down the runway until it ran out of runway or out of fuel. We need a force which will overcome the pull of gravity and permit the aircraft to leave the ground. This fourth force, the one which works against the force of gravity, is called lift. As you already know, the wings are the part of an aircraft through which we obtain most of the lift. How this lift is obtained is, like thrust, simple in theory but difficult to understand.

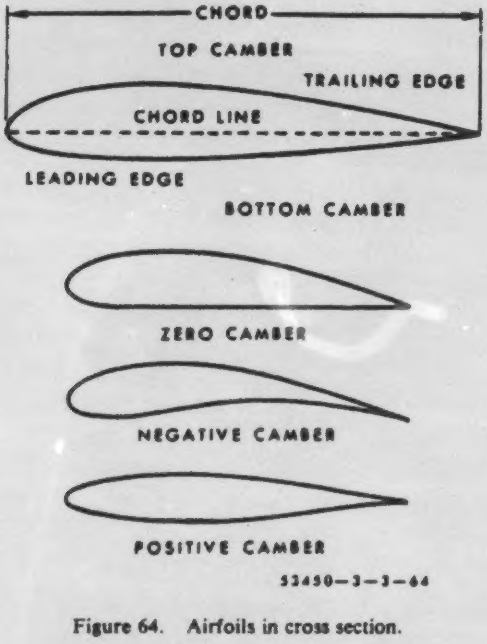


Figure 64. Airfoils in cross section.

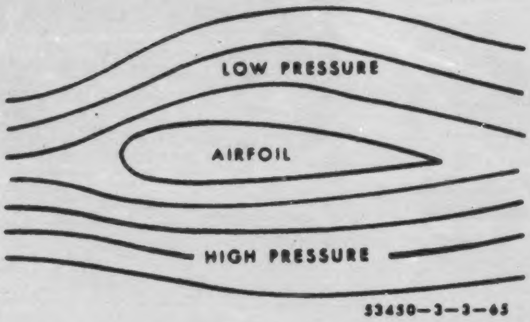


Figure 65. Lift.

15-10. **Principles of Flight.** The following paragraphs contain a brief discussion on the principles of flight.

15-11. *Airfoil.* Let us first review and explain the term "airfoil." An airfoil is any surface built to obtain a reaction upon itself from the air through which it passes. From the standpoint of an aircraft, such things as propeller blades, wings, stationary and movable control surfaces, and even the fuselage are termed "airfoils." The term is usually applied to the wings and empennage of an aircraft.

15-12. In figure 64, several cross-sections of wings or airfoils are illustrated. The front edge of wing is called the leading edge, and the rear the trailing edge. The chord of a wing is the distance from the leading edge to the trailing edge and is represented by a straight line called the chord line. The curve or departure from such a straight line (which the shape of the wing takes) is known as the camber. If the surface produces a convex (outward curving) surface, the camber is said to be positive. If concave (inward curving), the camber is said to be negative. The upper surface of an airfoil always has positive camber; the lower usually has positive camber also, but it can have zero (no curve) or negative camber.

15-13. *Bernoulli's principle.* In the 18th century a man named Bernoulli discovered that as the speed of air moving over a surface increases, the pressure on the surface decreases proportionately. How does this fact apply to the flight of an aircraft? Let us see what happens when an airfoil is moved through the air.

15-14. As movement starts, the mass of air molecules at the leading edge of the airfoil divides. Since the distance across the curved top surface is greater than that across the relatively flat bottom surface, the air molecules which go over the top must move faster than those going across the bottom in order to meet at the same time along the trailing edge. The faster airflow across the wing

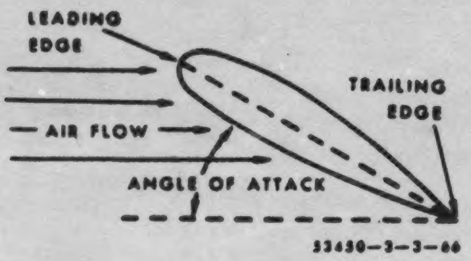


Figure 66. Angle of attack.

creates a lower pressure above the wing then below, as illustrated in figure 65.

15-15. The greater pressure below the wing tends to push into the lower pressure above. As long as air passes over the airfoil, this condition will exist. This is lift. When the movement of air is great enough, the lift will match the weight of the airfoil and all attached portions of it, and will then support the entire aircraft. As the speed of air across the wing increases even more, the lift exceeds the weight of the aircraft, and the aircraft rises.

15-16. Not all the air met by an airfoil is used in lift. Some of it creates resistance or drag and hinders forward motion. Lift and drag, the two forces into which air resistance is converted, depend on the angle of attack, speed of the airfoil, air density, and shape of the airfoil or wing.

15-17. *Angle of attack.* This is the angle between the chord mean centerline of the wing and its direction of motion relative to the air. Motion relative to the air, or relative airflow, is the direction of moving air in relation to the wing or airfoil. Figure 66 illustrates the angle of attack.

15-18. Lift and drag increase with an increase in the angle of attack up to a certain point called the critical angle. At this point, drag suddenly overcomes lift, and, as a result, the aircraft stalls. Drag continues to increase. The cause of stalling is turbulence. Turbulence is created by eddies of air (burbling) which break up the pattern of airflow on the upper surface of the wing. Notice the eddying or burbling of the air illustrated in figure 67.

15-19. At the critical angle, the air no longer clings to the top of the wing, and turbulence slows down the speed of the airflow. Pressure above the wing increases. With the loss of the pressure differential, the wing loses the lift necessary to maintain altitude. At this point, the aircraft stalls.

15-20. Wings and horizontal stabilizers are usually attached with a built-in angle of attack, known as the angle of incidence. When the fuselage is level longitudinally, the angle of incidence is measured between the chord of the wing and the horizontal plane.

15-21. *Speed of the airfoil.* As the speed of the airfoil moving through the air increases, the difference in pressure between the upper and lower airflow layers increases. So lift increases with speed—but not necessarily in direct proportion to it.

15-22. *Air density.* The density of air at 18,000 feet is about one-half of that at sea level. Remember that air becomes thinner as altitude increases; so any aircraft flying at high altitudes must increase its speed to maintain level flight. An aircraft's flight is also affected by temperature, since air density decreases as air temperature increases.

15-23. *Shape of an airfoil.* The shape of an airfoil affects lift in many ways. The greater the camber of curvature, up to a certain point, the greater the lift. An airfoil with a smooth surface has more lift in relation to drag than one with a rough surface. A rough surface produces turbulence, which reduces lift and increases drag.

16. Principles of Structural Repair

16-1. Methods of repairing structural portions of the aircraft are numerous and varied. No set of specific repair patterns has been found which apply in all cases. Information about design loads acting in various structural parts of the aircraft are not always available to the field repairman. The problem of repairing a damaged section is usually solved by duplicating the original part in strength, kind of material, and dimensions. In this section we will consider some general rules that you may apply, concerning the selection of materials and the forming of parts.

16-2. The general principles explained in this section are examples of typical repairs associated with the maintenance of aircraft. The repair methods in these examples are representative. Where specific technical order instructions are not available, you may duplicate these methods wherever applicable.

REMEMBER: If technical order instructions are available, always follow them.

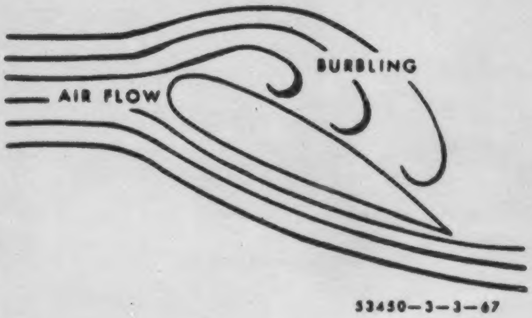


Figure 67. Critical angle of attack.

16-3. The first and one of the most important steps in repairing a structural damage is "sizing up" the job and making an accurate estimate of what is to be done. This "sizing up" includes an estimate of the best type and shape of patch to use; the type, size, and number of rivets needed; and the strength, thickness, and kind of material required to make the repaired member no heavier (or only slightly heavier) and just as strong as the original. You also inspect the surrounding members for evidence of corrosion and load damage so that you can estimate accurately the required extent of the "clean out" of the old damage. After completing the clean out, make the layout of the patch on paper, then transfer it to the sheet stock selected. Cut and chamfer the patch; form it so it matches the contour of that particular area and apply it.

16-4. **Maintaining Original Strength.** When you make any repair, you must observe certain fundamental rules if the original strength of the structure is to be maintained. Make the patch plate have a cross-sectional area equal to, or greater than, that of the original damaged section. If the member is subjected to compression or to bending loads, place the splice on the outside of the member to secure a higher resistance to such loads. If you cannot place the splice on the outside of the member, use material of a weight next heavier than the weight of the material used in the original.

16-5. To reduce the possibility of cracks starting from the corners of cutouts, make cutouts either circular or oval in shape. Where it is necessary to use a rectangular cutout, make the radius of curvature at each corner no smaller than ½ inch. Replace buckled or bent members, or reinforce them by attaching a splice over the affected area.

16-6. Be sure the material used in all replacements or reinforcements is similar to the material used in the original structure. If it is necessary to substitute an alloy weaker than the original, use material of a heavier gage to give equivalent cross-sectional strength. Never practice the reverse; that is, never substitute a lighter gage stronger material for the original. The reason for this apparent inconsistency is that one material can have greater tensile strength than another, but less compressive strength, or vice versa, as shown in the comparison of mechanical properties of alloys 2024T and 2024–T80.

16-7. If alloy 2024T were to be substituted for alloy 2024–T80, the substitute material would have to be thicker unless the reduction in compressive strength were known to be acceptable. On the other hand, if 2024–T80 material were substituted for 2024T stock, the substitute material would have to be thicker unless the reduction in tensile strength were known to be acceptable. Similarly, the buckling and torsional strength of many sheet metal and tubular parts are dependent primarily upon the thickness rather than the allowable compressive and shear strengths of the material. Therefore, a substitute thinner than the original will reduce considerably the buckling and torsional strength of a part, even though the thinner substitute material has higher compressive and shear strengths. Information on aluminum alloy sheet substitution is contained in TO 1–1A–1, *General Manual for Structural Repair*.

16-8. When forming is necessary, be particularly careful. Heat-treated and cold-worked alloys will stand very little bending without cracking. Soft alloys, on the other hand, are easily formed but are not strong enough for primary structures. Strong alloys can be formed in their annealed condition and heat-treated to develop their strength before assembling.

16-9. In some cases, if the annealed metal is not available, you can heat the metal, quench it according to regular heat-treating practices, and form it before age-hardening sets in. The forming should be completed in about half an hour after quenching or the material will become too hard to work. If you use a brake to form a section, place a thin piece of soft metal over the brake jaws to prevent scraping and scratching the surface of the sheet.

16-10. Determine the size of rivets for any repair by referring to the rivets (used by the manufacturer) in the next parallel rivet row inboard on the wing or forward on the fuselage. Another method of determining the size of rivets to be used is to multiply the thickness of the skin by 3 and use the nearest larger sized rivet corresponding to that figure. Thus, for example, if the skin thickness is .040 inch, multiply .040 by 3 which equals .120, and use the next larger size rivet, ⅛ inch (.125 inch).

16-11. All repairs made on structural parts of aircraft require a definite number of rivets in order to restore the original strength. This number varies according to the thickness of the material being repaired and the size of the damage. Determine the number of rivets or bolts required by referring to a similar splice made by the manufacturer, or by using the following rivet formula.

16-12. The number of rivets to be used on each side of the break is equal to the *length of the break* times the *thickness of the material* times 75,000 divided by the *shear strength* or *bearing strength*, whichever is the smaller of the two.

16-13. The *length of the break* is measured perpendicular to the direction of the general stress running through the damaged area.

TABLE 11
SINGLE SHEAR STRENGTH TABLE

*Single Shear Strength of Aluminum-Alloy Rivets (Pounds)									
Composition of Rivet (Alloy)	Ultimate Strength of Rivet Metal (Pounds Per Square Inch)	Diameter of Rivet (Inches)							
		1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
2117 T	27,000	83	186	331	518	745	1,325	2,071	2,981
2017 T	30,000	92	206	368	573	828	1,472	2,300	3,313
2024 T	35,000	107	241	429	670	966	1,718	2,684	3,865

*Double shear strength is found by multiplying the above values by 2.

33450—3—3—T13

16-14. The *thickness of the material* is the actual thickness of the piece of material being repaired and is measured in thousandths of an inch.

16-15. The 75,000 figure used in the formula is an assumed stress load value of 60,000 psi increased by a safety factor of 25 percent. It is a constant value.

16-16. The *shear strength* is taken from table 11. It is the amount of force required to cut a rivet holding two or more sheets of material together. If the rivet is holding two parts, it is under single shear; if it is holding three sheets or parts, it is under double shear. To determine the shear strength, the diameter of the rivet to be used must

TABLE 12
BEARING STRENGTH TABLE

Thickness of Sheet (Inches)	Diameter of Rivet (Inches)							
	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
0.014	71	107	143	179	215	287	358	430
.016	82	123	164	204	246	328	410	492
.018	92	138	184	230	276	369	461	553
.020	102	153	205	256	307	410	412	615
.025	.128	192	256	320	284	512	640	768
.032	164	245	328	409	492	656	820	984
.036	184	276	369	461	553	738	922	1,107
.040	205	307	410	512	615	820	1,025	1,230
.045	230	345	461	576	691	922	1,153	1,383
.051	261	391	522	653	784	1,045	1,306	1,568
.064		492	656	820	984	1,312	1,640	1,968
.072		553	738	922	1,107	1,476	1,845	2,214
.081		622	830	1,037	1,245	1,660	2,075	2,490
.091		699	932	1,167	1,396	1,864	2,330	2,796
.102		784	1,046	1,307	1,569	2,092	2,615	3,138
.125		961	1,281	1,602	1,922	2,563	3,203	3,844
.156		1,198	1,598	1,997	2,397	3,196	3,995	4,794
.188		1,445	1,927	2,409	2,891	3,854	4,818	5,781
.250		1,921	2,562	3,202	3,843	5,125	6,405	7,686
.313		2,405	3,208	4,009	4,811	6,417	7,568	9,623
.375		2,882	3,843	4,803	5,765	7,688	9,068	11,529
.500		3,842	5,124	6,404	7,686	10,250	12,090	15,372

33450—3—3—T14

be known. This is determined by multiplying the thickness of the material by three. An example would be: material thickness .040 multiplied by 3 equals .120; the rivet selected would be ⅛ inch (.125 inch) in diameter.

16-17. The *bearing strength* is a value taken from table 12. It is the amount of tension required to pull a rivet through the edge of two sheets riveted together, or to elongate the hole. The diameter of the rivet to be used and the thickness of material being riveted must be known to use the bearing strength chart. The diameter of the rivet would be the same as that used when determining the shear strength value. Thickness of material would be that of the material being repaired.

16-18. Once you understand the derivation and meaning of terms used in the rivet formula (as explained in the preceding paragraphs), you can reduce the formula to the following:

$$\frac{L \times T \times 75{,}000}{S \text{ or } B}$$

16-19. For example of the use of the formula let's determine the number of 2117T rivets needed to repair a break 2¼ inches long in material .040-inch thick. Formula:

$$\frac{L \times T \times 75{,}000}{S \text{ or } B}$$

Information needed:

L = 2¼ (2.25) inches
T = .440-inch
Size of rivet: .040 × 3 = .120, so rivet must be ⅛ inch, or .125
S = 331 (from the shear strength chart)
B = 410 (from the bearing strength chart)
S = 331 is smaller than B = 410

Substitution and result:

$$\frac{2.25 \times .040 \times 75{,}000}{331} = \frac{6750}{331}$$

$$= 20.39 \text{ rivets for each side}$$

16-20. Since any fraction must be considered as a whole number, the actual number of rivets required would be 21 for each side, or 42 rivets for the entire repair.

16-21. **Maintaining Original Contour.** Form all repairs so that they fit the original contour perfectly. A smooth contour is especially desirable when making patches on the smooth external skin of fast aircraft.

16-22. Keep the weight of all repairs to a minimum. Make the size of the patch as small as practicable and use no more rivets than are necessary. Often repairs disturb the original balance of the structure. By adding excessive weight in each repair, you may unbalance the aircraft so much that it will require adjustment of the trim and balance tabs. In critical places, such as the spinner of the propeller, a repair will require application of balancing patches so that a perfect balance of the propeller assembly can be maintained.

16-23. **General Structural Repair.** Aircraft structural members are built to perform a specific function or to serve a definite purpose. In the repair of aircraft, the objective is to restore the damaged part to its original condition. Very often, replacement is the only way in which this can be done effectively. When repair of a damaged part is possible, study the part carefully so that you can fully understand its purpose or function.

16-24. Strength may be the principal requirement in the repair of certain structures, while others may need entirely different qualities. For example, fuel tanks, floats, and hulls must be protected against leakage; but cowlings, fairings, and similar such parts must have such properties as neat appearance, streamlined shape, and accessibility. The function of any damaged part must be determined so that you can make the repair meet the requirements.

16-25. *Inspection of damage.* When you visually inspect the damage, remember that there may be other kinds of damage than those caused by flying missiles from the exterior, such as flak. A rough landing may overload one of the landing gear, causing it to become sprung. During inspection and "sizing up of the repair job," consider how far the damage caused by the sprung shock strut extends in to supporting structural members.

16-26. A shock occurring at one end of a member is transmitted throughout its length; therefore, inspect all rivets, bolts, and attaching structures along the complete member for evidence of damage. Make a close examination for rivets that have partially failed and for holes which are elongated.

16-27. Another kind of damage for which you must watch is that caused by weathering or corrosion. You can detect corrosion damage of aluminum material by the white crystalline deposit that may be found around loose rivets, scratches, or any portions of the structure that is a natural spot for moisture to settle.

16-28. If you cannot make visual inspection of inside skin surfaces without disassembly, then inspect the part by rapping the outside skin in various places with the knuckles. The presence of severe corrosion will become evident when light rapping causes slight dents in the material or causes a white dust to rise.

16-29. *Classification of damage.* Damage is grouped into four general classes. The availability or lack of repair materials and time are the most important factors in determining whether a part is repaired or replaced. The classes and a general description of each type damage follows.

16-30. A damage which does not affect the structural integrity of the member involved, or a damage which can be corrected by a simple procedure without placing flight restrictions on the aircraft, is classified as *negligible damage.* Small dents, scratches, cracks, or holes that can be repaired by smoothing, sanding, stop drilling, or hammering out, or otherwise repaired without the use of additional materials, fall in this classification.

16-31. A damage repairable by patching is any damage exceeding negligible damage limits which can be repaired by bridging the damaged area of component with a splice material. The splice or patch material used in internal or riveted and bolted repairs is normally the same type of material as the damaged part, but one gage heavier. In a patch repair, filler plates of the same gage and type of material as that in the damaged component may be used for bearing purposes or to return the damaged part to its original contour. Such damage is classified as *damage repairable by patching.*

16-32. Any damage which can be repaired by cutting away the damaged section, replacing the removed portion with a like section of the damaged component and securing the insertion with splices at each end is classified as *damage repairable by insertion.*

16-33. Replacement of an entire part is considered when one or more of the following conditions exist:

- When a complicated part has been extensively damaged.
- When surrounding structure or inaccessibility makes repair impractical.
- When damaged part is relatively easy to replace.
- When forged or cast fittings are damaged beyond the negligible limits.

Such damage is classified as *damage necessitating replacement of parts.*

16-34. **Corrosion Control.** Earlier in this course, you made extensive study of corrosion and corrosion control. We need to review this information since corrosion is a type of damage.

16-35. Corrosion control and treatment are of major importance to all aircraft and missile maintenance personnel. They are vital because corrosion of equipment and primary structures greatly affects the capability as well as the operational and structural effectiveness of any given weapon system. Economy is another important reason. Severe corrosion ultimately weakens primary structures sufficiently to require replacement or reinforcement in order to sustain designed loads. Weakening usually necessitates a major repair that can be costly, time consuming, and result in loss of weapon system effectiveness.

16-36. Scheduled inspections and preventive measures are essential to determine weapon system status and to provide for early correction of weaknesses. Preventive maintenance lessens the total amount of labor used and expense required. It in-

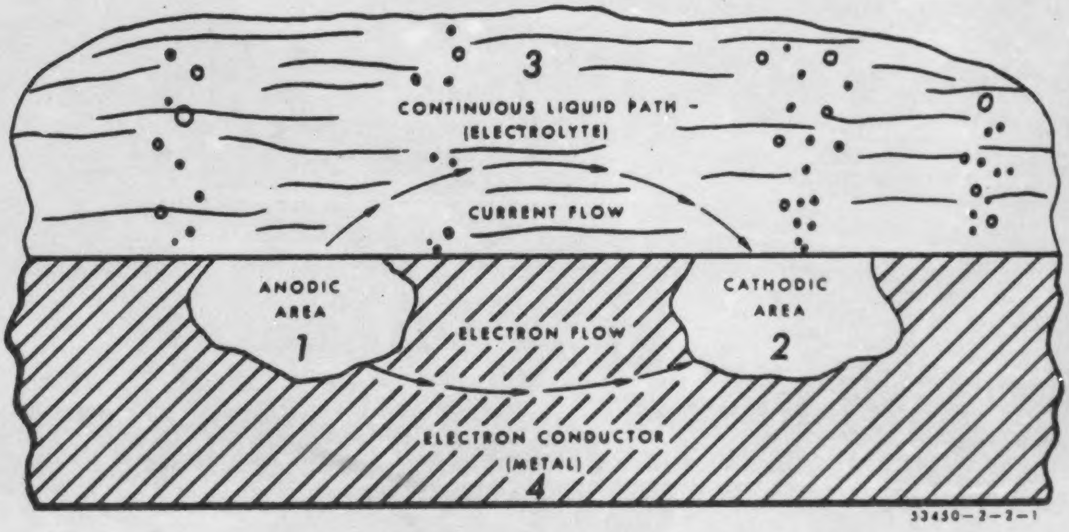

3
CONTINUOUS LIQUID PATH - (ELECTROLYTE)
CURRENT FLOW
ANODIC AREA
1
CATHODIC AREA
2
ELECTRON FLOW
ELECTRON CONDUCTOR (METAL)
4
53450-2-2-1

Figure 68. Conditions for electrochemical corrosion.

sures that corrosion will not prevent a weapon system from performing the designed functions.

16-37. Most metals are subject to corrosion. Corrosion can be minimized by use of corrosion resistant metals and finishes consistent with weight and strength design factors of the weapon system. The principal corrosion preventive used in airframe structures is aluminum alloy sheet coated on both sides with pure aluminum. Under normal conditions, alclad aluminum is highly resistant to corrosion; however, accumulated soil, salts, industrial fumes, and moisture will cause pitting of the alclad surface.

16-38. Nonclad metals require some special preventive measures to guard against corrosion. Aluminum alloys, for example, are usually either anodized or chemically treated and painted with an organic finish. The internal structure of airframes is usually painted. Steel (except most stainless steels) and metals such as bronze and brass require cadmium or zinc plating, conversion coating, paint, or all three for protection. Magnesium requires special chemical treatments and paint finishes.

16-39. Corrosion is defined as the deterioration of a metal by reaction to environment. Corrosion occurs because most metals tend to return to their natural state (iron in the presence of moist air reverts to its natural state, iron oxide). Metals also corrode by the direct addition of the metal to a chemical.

16-40. For you to understand the causes and results of the types of corrosion, let's review electrochemical reaction or corrosion. Four conditions must exist before electrochemical corrosion can occur. These are illustrated in figure 68. These conditions are:

- Something that corrodes the metal (metal anode).
- A cause (cathode).
- A continuous liquid path (electrolyte, usually condensate and salt or other contaminations).
- A conductor to carry the flow of electrons from the anode to the cathode. This conductor is usually in a form that provides for metal-to-metal contact (rivets, bolts, welds, etc.).

16-41. The elimination of any one of the four conditions automatically stops corrosion. As an example, an organic film applied to the surface of the metal will prevent the electrolyte from connecting the cathode and the anode and the current cannot flow; therefore, no corrosion will occur.

16-42. At normal atmospheric temperatures, metals do not corrode appreciably without moisture, but moisture in the air is usually enough to start action. Oxygen is also usually essential for serious corrosion to take place in ordinary water at room temperature. Other factors which affect a metal's tendency to corrode are: acidity or alkalinity of the conductive medium (pH factor); stability of the corrosion products; biological organisms, particularly anaerobic bacteria; variation in composition of the corrosive medium; temperature; etc.

16-43. The initial rate of corrosion is usually much greater than the rate after a short time because the oxide film which forms on a metal surface tends to protect the metal underneath. This is not true for stress corrosion.

16-44. When weapons systems constructed of many different types of metals must perform under varied climatic conditions, the corrosion problem becomes complex. The presence of salts on metal surfaces (from sea coast operations or sites, blast deposits after firing guns or ATO bottles, urine spray, spillage of fuel oxidizers, or taxiing over runways where various salts have been used to decrease ice formation) increases the electrical conductivity of any moisture present and accelerates corrosion.

16-45. Moisture collects on dirt particles. The maintenance of clean surfaces on passive metals or alloys is more important than it is on the surfaces of plain carbon steel or copper-base alloys. If beginning corrosion areas develop, the combination of small active anodes to large passive cathodes causes severe pitting. This principle also applies to metals which have been passivated by chemical treatment as well as to metals which develop passivation that is due to environmental conditions (e.g., aluminum, stainless steel).

16-46. Alloys that owe their corrosion resistance to passivity are particularly susceptible to accelerated corrosion within crevices. This phenomenon is caused by formation of an oxygen cell resulting from lower oxygen concentration in the crevice. For these reasons, cleanliness must be maintained and corrosion preventive measures must be observed even on corrosion resistant materials.

16-47. Because some areas of a weapon system are subjected to more corrosive substances than others, the possibility of a corrosion problem and the necessary control measures vary accordingly. Nearly all corrosive attacks begin on the surface of the metal exposed to corrosive environment. If allowed to progress, corrosion works down into the core of the material. Since corrosion never originates in the core, there will always be evidence on the surface when an attack is in progress.

16-48. Corrosion has been categorized and typed in many ways. For descriptive purposes the types are reviewed under what is considered the most commonly accepted titles.

TABLE 13
GROUPING OF METAL ALLOYS

Group I	Magnesium and its alloys; aluminum alloys 5052, 5056, 5356, 6061, and 6063.
Group II	Cadmium, zinc, and aluminum and their alloys (including the aluminum alloys in Group I).
Group III	Iron, lead, and tin and their alloys (except stainless steel).
Group IV	Copper, chromium, nickel, silver, gold, platinum, titanium, cobalt, and rhodium and their alloys; stainless steel and graphite.
Metals classified in the same group are considered similar to one another. Metals classified in different groups are considered dissimilar to one another.	

33430—3—3—T15

16-49. *Uniform etch corrosion.* The surface effect produced by most direct chemical attacks (as by an acid) is a uniform etching of the metal. On a polished surface this type of corrosion is first seen as a general dulling of the surface. If such corrosion is allowed to continue, the surface becomes rough and, possibly, frosted in appearance.

16-50. *Pitting corrosion.* The most common effect of corrosion on aluminum and magnesium alloys is called pitting. It is first noticeable as a white or gray powdery deposit, similar to dust, which blotches the surface. When the deposit is cleaned away, thin pits or holes can be seen in the surface. Pitting corrosion may also occur in other types of metal alloys.

16-51. *Integranular corrosion.* Intergranular corrosion is an attack on the grain boundaries of material. A highly magnified cross section of any commercial alloy shows the granular structure of the metal. It consists of quantities of individual grains, and each of these tiny grains has a clearly defined boundary which chemically differs from the metal within the grain center. The adjacent grains of different elements react with each other as anode and cathode when in contact with an electrolyte (conductive medium). Rapid selective corrosion at the grain boundary occurs.

16-52. Exfoliation is a form of intergranular corrosion. It shows itself by "lifting up" the surface grains of a metal by the force of expanding corrosion products occurring at the grain boundaries just below the surface. It is visible evidence of intergranular corrosion. It is most often seen on extruded sections where grain thicknesses are usually less than in rolled forms.

16-53. *Galvanic corrosion.* Galvanic corrosion occurs when dissimilar metals are in contact and an external circuit is provided by the presence of a buildup of corrosion at the joint between the metals. For example, aluminum and magnesium skins riveted together in an aircraft wing form a galvanic couple if moisture and contaminations are present. When aluminum pieces are attached with steel bolts or screws, galvanic corrosion can occur between the aluminum and the steel.

16-54. Metals grouped together in table 13 have no strong tendency to produce galvanic corrosion and are relatively safe to use in contact with each other. The coupling of metals from different groups and distant from each other in the chart usually results in galvanic or accelerated corrosion of the metal higher on the list. The farther apart the metals are in the chart, the greater is the galvanic tendency, as determined by measurement of the electrical potential difference between them.

16-55. All commonly used metals cause corrosion of magnesium in strong salt environment. Cadmium or zinc plating on the more cathodic metals, such as iron and steel, reduces galvanic corrosion. Tin-plated metal, when connected to magnesium, causes less corrosion than cadmium or zinc plated metal. In this unusual circumstance, the tin polarizes and acts as an insulator. This is a contradiction; so it must be kept in mind that the galvanic series of metals and alloys are used for general information and that exceptions do exist.

16-56. The use of aluminum alloys containing magnesium, such as 5052 and 5053, usually reduces galvanic corrosion of the magnesium alloys and also reduces simultaneous corrosion of the aluminum. Under severe exposure when the contact of magnesium alloys and plated steel bolts is necessary, use 5052 aluminum washers to prevent severe galvanic attack.

16-57. Continuity of the liquid path is also broken by the use of vinyl or polyester tapes. When conditions favorable to galvanic corrosion are unavoidable, always protect both portions of a couple. A break in the protective coating on the anodic surface causes severe pitting if the cathodic surface is not protected because of the concentration of current upon the relatively small exposed area.

16-58. When practical, use rivets, bolts, and other fasteners made of the same material as the main structure. When not practical, select materials lower in the chart in order to distribute the anodic attack over the larger of the two coupled metals. This is particularly important where the fasteners are subjected to high stress and where the safety factor is low. However, the structural strength of the aircraft/missile must not be endangered by substituting incorrect parts. Refer to the specific technical orders involved or to the prime support systems manager.

16-59. *Concentration cell corrosion.* Concentration cell corrosion occurs when two or more areas of a metal surface are in contact with different concentrations of the same solution. There are three general types of concentration cell corrosion: metal ion concentration cells, oxygen concentration cells, and active-passive cells. TO 1–1–2, *Corrosion Control and Treatment for Aerospace Equipment*, gives a detailed explanation of these types.

16-60. *Stress Corrosion Cracking*. Stress corrosion cracking is caused by the simultaneous effects of tensile stress and corrosion. Stress is internal or applied. Internal stress is produced by nonuniform deformation during cold working, by unequal cooling from high temperatures, and by internal structural rearrangement involving volume changes. Stresses induced when a piece is deformed, those induced by press and shrink fits, and those in rivets and bolts are internal stresses.

16-61. Concealed stress is more important than design stress, especially because stress corrosion is difficult to recognize before it has overcome the design safety factor.

16-62. The magnitude of the stress varies from point to point within the metal. Stresses in the neighborhood of the yeld strength are generally necessary to promote stress corrosion cracking; but failures have occurred at lower stresses.

16-63. *Fatigue corrosion*. Fatigue corrosion is a special case of stress corrosion caused by the combined effects of cyclic stress and corrosion. No metal is immune to some reduction of its resistance to cyclic stressing if the metal is in a corrosive environment. Damage from fatigue corrosion is greater than the sum of the damage from both cyclic stresses and corrosion.

16-64. Fatigue corrosion failure occurs in two stages. During the first stage, the combined action of corrosion and cyclic stresses damages the metal by pitting and cracking to such a degree that fracture by cyclic stressing ultimately occurs, even if the corrosive environment is completely removed. The second stage is essentially a fatigue stage in which failure proceeds by propogation of the crack and is controlled primarily by stress concentration effects and the physical properties of the metal.

16-65. Fracture of a metal part which is due to fatigue corrosion generally occurs at a stress far below the fatigue limit in laboratory air, even though the amount of corrosion is unbelievably small. For this reason, protection of all parts subject to alternating stress is particularly important wherever practical, even in environments that are only mildly corrosive.

16-66. **Inspection for Corrosion.** Without proper and systematically performed inspections and maintenance, corrosion will seriously damage any weapon system. Inspect all equipment at each periodic inspection for signs of corrosion.

16-67. Typical locations that require close inspection are:

a. Unpainted aluminum areas.

b. Skin seams.

c. Lap joints.

d. Niches and crevices where traces of cleaning compound have accumulated.

e. Areas where moisture does not evaporate as rapidly as areas exposed to direct sunlight and air.

f. Drain holes that may be clogged.

g. Structures underneath floorboards.

h. Faying surfaces.

i. Fittings, braces, and compound parts inside the aircraft where foreign matter or moisture may accumulate because of improper drainage or disposal outlets.

j. Areas where dissimilar metals may be in contact.

k. Spotwelds.

l. Piano type hinges.

m. Exhaust gas paths.

n. Wheel wells, landing gear, dive brake, and similar areas.

o. Heavy or tapered aluminum alloy skin surfaces.

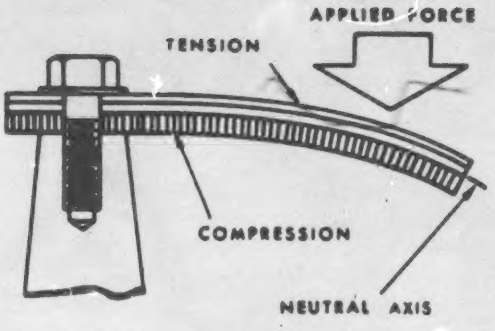
16-68. **Corrosion Removal and Treatment.** As an airframe repairman, part of your assigned duties may be to inspect a weapon system or equipment for evidence of corrosion. If the inspection reveals evidence of corrosion in any area, removal of the corrosion and application of preventatives is a must.

16-69. The degree to which you will be involved in corrosion removal and treatment will depend on the directives and SOPs of your assigned base and unit and on the availability of qualified personnel, equipment, and materials necessary for the task.

16-70. TO 1–1–2, *Corrosion Control and Treatment for Aerospace Equipment*, contains detailed information on removal procedures and application of preventives for the various types of metals used in the manufacture of aircraft. Methods, materials, and equipment used in preventive maintenance painting are also discussed in this technical order.

16-71. Because of the detailed explanation found in TO 1–1–2, methods, procedures, equipment, and materials used for corrosion removal and treatment are not discussed in this volume. Once the inspection for corrosion determines necessity for removal and treatment, follow the instructions outlined in the technical order.

16-72. When inspections locate corrosion so severe that it necessitates the removal of the damaged component or part, repair procedures as outlined in the specific –3 technical order for the aircraft must be followed.



53450—3—3—69

Figure 69. Stresses.

16-73. **Stress in Structural Members.** Forces act on the aircraft whether it is on the ground or in flight. These forces cause pulling, pushing, or twisting within the various members of the aircraft structure. While the aircraft is on the ground, the weight of the wings, fuselage, engines, and empennage causes forces to act downward on the wing and stabilizer tips, along the spars and stringers, and on the bulkheads and formers. These forces are passed on from member to member, causing bending, twisting, pulling, compression, and shearing.

16-74. As the aircraft takes off, most of the forces in the fuselage continue to act in the same direction; but, because of the motion of the aircraft, they increase in intensity. However, the forces on the wingtips and the wing surfaces, reverse direction and instead of being downward forces of weight, they become upward forces of lift. First the forces of lift are exerted against the skin and stringers, then are passed on to the ribs, and finally are transmitted through the spars to be distributed through the fuselage to any deadweight items carried in the fuselage.

16-75. The wings bend upward at the end and may flutter slightly during flight. This wing bending cannot be ignored by the manufacturer in the original design and construction, and cannot be ignored by the metal repairman during maintenance. It is quite surprising how an aircraft structure composed of structural members and skin rigidly riveted or bolted together, such as a wing, can bend or act so much like a large spring leaf.

16-76. The five types of stresses in an aircraft are described as tension, compression, shear, bending, and torsion (or twisting). The first three are commonly called the basic stresses; the last two, the combination stresses. Stresses rarely act singly but usually in combinations. The most important types of stresses from the standpoint of the metal repairman are bending, torsion, and shear.

16-77. *Tension.* Tension (or tensile stress) is the force per unit area tending to stretch a structural member. In figure 69, note the condition of the metal strap after stretching. Drilling the bolt hole in the strap removed much of the material and reduced the cross-sectional area. Since the load is constant from one end of the strap to the other and the hole cannot carry any of the load, the stress in the reduced section is greatly increased (per unit area). The area on each side of the hole is carrying not only its normal share of the load but also that part of the load which should have been carried by the removed material. Obviously, if the load were increased until the strap failed, the break would occur in the material near the hole.

16-78. The strength of a member in tension is determined on the basis of its gross area (or total area), but calculations involving tension must take into consideration the net area of the member. Net area is defined as "the gross area minus that removed by drilling holes or by making other changes in the section." Placing rivets or bolts in holes makes no appreciable difference in added strength, as the rivets or bolts will not transfer tensional loads across holes in which they are inserted.

16-79. *Compression.* Compression (or compressive stress) is the force per unit area which tends to shorten (or compress) a structural member at any cross section. Under a compressive load, an undrilled member will be stronger than an identical member with holes drilled through it. However, if a plug of equivalent or stronger material is fitted tightly in a drilled member, it will transfer compressive loads across the hole and the member will carry approximately as large a load as if the hole were not there. Thus, for compressive loads, the gross or total area may be used in determining the stress in a member if all holes are tightly plugged with equivalent or stronger material.

16-80. *Shear.* Shear is the force per unit area which acts in such a way as to slide adjacent particles of material past each other. The term "shear" is used because it is a sideways stress of the type that is put on a piece of paper or a sheet of metal when it is cut with a pair of shears. Shear stress concerns you chiefly from the standpoint of rivet and bolt applications, particularly when attaching sheet stock, for if a rivet used in a shear application gives way, the rivet parts are pushed sideways.

16-81. *Bending.* Bending (or beam stress) is actually a combination of two forces acting upon a structural member at one or more points. In figure 69 note that the bending stress causes a tensile stress to act on the upper half of the beam and a compressive stress on the lower half. These

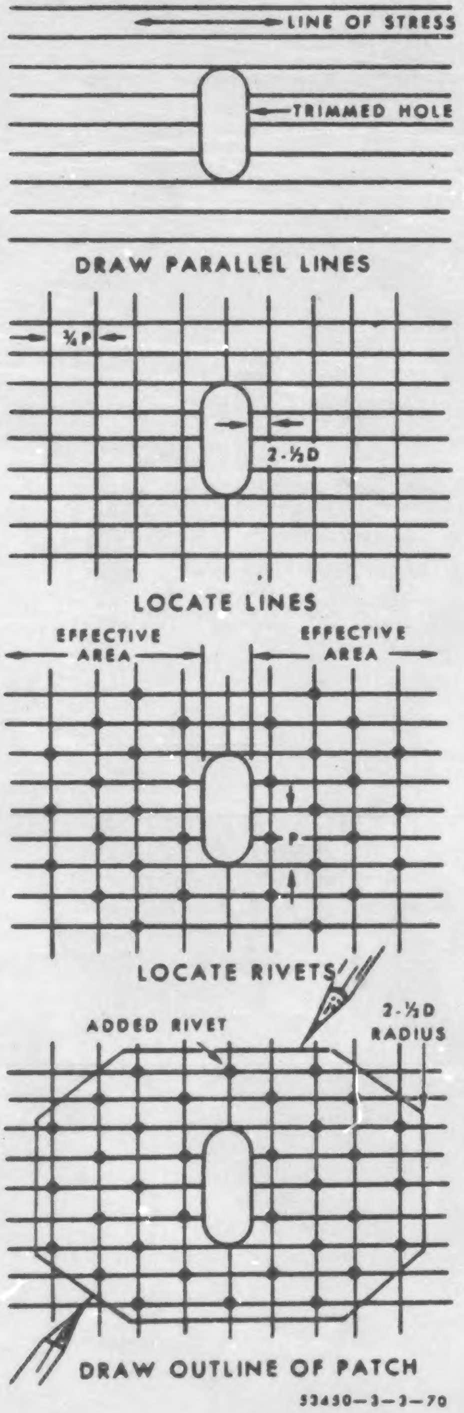


Figure 70. Elongated patch.

stresses act oppositely on the two sides of the centerline of the member, which is called the neutral axis. Since these forces acting in opposite directions are next to each other at the neutral axis, the greatest shear stress occurs along this line, and none exists at the extreme upper or lower surfaces of the beam.

16-82. *Torsion.* Torsion (or twisting stress) is the force which tends to twist a structural member. The stresses arising from this action are shear stresses caused by the rotation of adjacent planes past each other around a common reference axis at right angles to these planes. This action may be illustrated by a rod fixed solidly at one end and twisted by a weight placed on a lever arm at the other, producing the equivalent of two equal and opposite forces acting on the rod at some distance from each other. A shearing action is set up all along the rod, with the centerline of the rod representing the neutral axis.

17. Specific Structural Repair

17-1. Before discussing any type of a specific repair made on an aircraft we remind you that the methods, procedures, and materials mentioned in the following paragraphs are typical and are not to be used as the absolute authority for the repair. When you are assigned the task of repairing a damaged component or part of any weapon system, first consult the applicable section of the –3 technical order for the aircraft. Normally, a similar repair will be illustrated and the types of material, rivets, rivet spacing, and the methods and procedures to be used will be listed. Any additional knowledge needed to make a repair will also be detailed.

17-2. If you fail to find the necessary information in the –3 technical order, make an attempt to find a similar repair or assembly installed by the manufacturer of the aircraft. Another source of information on methods and procedures to be used in making repairs is TO 1–1A–1, *General Manual for Structural Repair.*

17-3. Earlier you were told to always use the technical order with the latest date. This is still true. If any doubt exists as to the proper reference to use, consult your shop supervisor.

17-4. **Flush Skin Repair.** You can repair minor damage to the outside skin of an aircraft by applying a patch to the inside of the damaged sheet. Install a filler plug in the hole made by the removal of the damaged skin area. It plugs the hole and forms a smooth outside surface necessary for aerodynamic smoothness of modern-day aircraft.

17-5. The size and shape of the patch is determined in general by the number of rivets required in the repair. If not otherwise specified by the technical orders, calculate the required number of rivets by using the rivet formula. Make the patch plate of the same material as the original skin and of the same thickness or of the next greater thickness.

17-6. *Elongated octagonal patch.* Whenever possible, use an elongated octagonal patch for repair of the smooth skin. This type of patch provides a good concentration of rivets within the critical stress area, eliminates dangerous stress concentrations, and is very simple to lay out. This patch may vary in length according to the condition of the repair.

17-7. Follow the steps shown in the paper layout of this patch illustrated in figure 70. First, draw the outline of the trimmed-out damage. Then, using a spacing of 3 to 4 diameters of the rivet to be used, draw lines running parallel to the line of stress. Locate the lines for perpendicular rows 2½ rivet diameters from each side of the cutout, and space the remaining lines ¾ rivet pitch apart.

17-8. Locate the rivet spots on alternate lines perpendicular to the stress lines in such a way as to produce a stagger between the rows and to establish a distance between rivets (in the same row) of about 6 to 8 rivet diameters. After you have located the proper number of rivets on each side of the cutout, add a few more if necessary so that the rivet distribution will be uniform. At each of the 8 corners, swing an arc of 2½ rivet diameters from each corner rivet. This locates the edge of the doubler. Using straight lines, connect these arcs to complete the layout.

17-9. *Round patch.* Use the round patch for flush repairs of small holes in smooth sheet sections. The uniform distribution of rivets around its circumference makes it an ideal patch to use in places where the direction of the stress is unknown or where it is known to change frequently.

17-10. If you use a two-row round patch, as illustrated in figure 71, first draw the outline of the trimmed area on paper. Draw two circles—one with a radius equal to the radius of the trimmed area plus the edge distance, and the other with a radius ¾-inch larger. Determine the number of rivets to be used and space two-thirds of them equally along the outer row. Using any two adjacent rivet marks as centers, draw intersecting arcs; then draw a line from the point of intersection of the arcs to the center of the patch. Do the same with each of the other pairs of rivet marks. This will give half as many lines as there are rivets in the outer row. Locate rivets where these lines intersect the inner circle. Then transfer the layout to the doubler material, adding regular outer edge material of 2½ rivet diameters to the doubler.

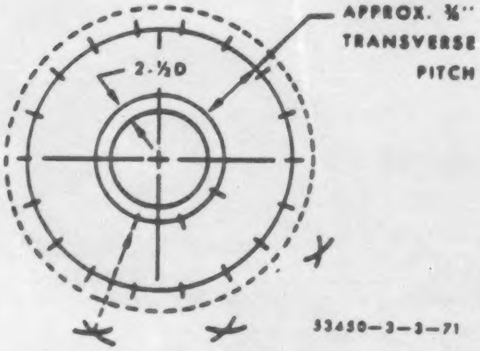


Figure 71. Layout of two-row round patch.

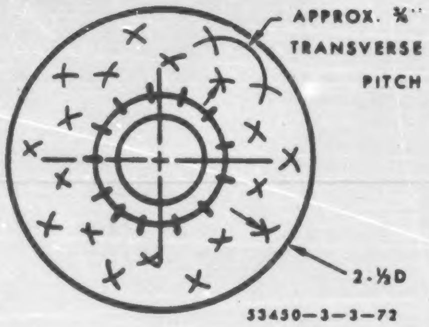


Figure 72. Layout of a three-row round patch.

17-11. Use a three-row round patch as illustrated in figure 72 if the total number of rivets is large enough to cause a pitch distance smaller than the minimum for a two-row patch. Draw the outline of the area on paper; then draw a circle with a radius equal to that of the trimmed area plus the edge distance. Equally space one-third of the required number of rivets in this row. Using each of these rivet locations as a center, draw arcs having a ¾-inch radius. Where they intersect, locate the second row of rivets. Locate the third row in a similar manner. Then allow extra material of 2½ rivet diameters around the outside rivet row. Transfer the layout to the patch material.

17-12. After laying out and cutting the patch, remove the burrs from all edges. Chamfer the edges of all external patches to a 45° angle and turn them slightly downward so that they will fit close to the surface as illustrated in figure 73.

17-13. *Panel repair.* In aircraft construction, a panel is any single sheet of metal covering. A panel section is the part of a panel between adjacent stringers and bulkheads. Where a section of skin is damaged to such an extent that it is impossible to install a standard skin repair, a special type of repair is necessary. The particular type of repair required depends on whether the damage is reparable outside the member, inside the member, or to the edges of the panel.

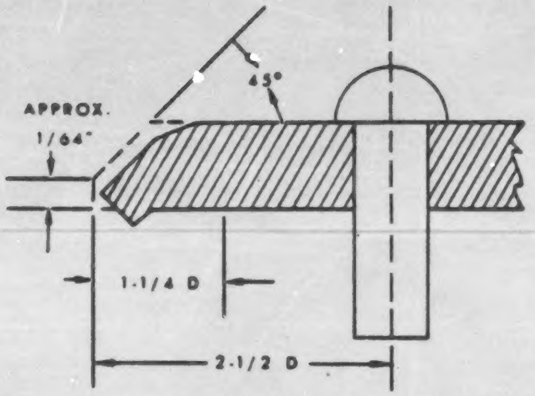


Figure 73. Camfering and turning edge of patch.

17-14. A damage which, after being trimmed, has less than 8½ manufacturer's rivet diameters of material inside the members requires a patch which extends over the members, plus an extra row of rivets along the outside of the members. On damages which, after being trimmed, have 8½ rivet diameters or more of material, extend the patch to include the manufacturer's row of rivets and add an extra row inside the members. Damage which extends to the edge of a panel requires only one row of rivets along the panel edge (unless the manufacturer used more than one row). The repair procedure for the other edges of the damage follows the previously explained methods.

17-15. The procedures for making all three types of panel repairs are similar. Trim out the damaged portion to the allowances mentioned in the preceding paragraph. For relief of stresses at the corners of the trim out, round them to a minimum radius of ½ inch. Lay out the new rivet row with a transverse pitch of approximately 5 rivet diameters and stagger the rivets with those put in by the manufacturer.

17-16. Cut the patch plate from material of the same thickness as the original or the next greater thickness. Allow an edge distance of 2½ rivet diameters. At the corners, strike arcs having the radius equal to the edge distance. Chamfer the edges of the patch plate for a 45° angle and form the plate to fit the contour of the original structure. Turn the edges downward slightly so the edges fit tight.

17-17. Place the patch plate in its correct position, drill one rivet hole, and temporarily fasten the plate in place with a fastener. Using a hole finder, locate the position of a second hole, drill it, and insert a second fastener. Then, from the back side and through the original holes, locate and drill the remaining holes. Remove the burrs from the rivet holes and apply corrosion protective material to the contacting surfaces before riveting the patch into place.

17-18. *Seals and baffles.* Aircraft seals are used to keep air and other gases within their proper channels. Certain types of seals are used as heat barriers between one structure or component and another. Such a seal is between the stainless steel tail cone of a jet engine and the aluminum alloy fuselage aft section. Other types of seals are found on access doors, cowl flaps, canopies, bulkhead doors of pressurized compartments, and jet engines.

17-19. Some of the materials and material combinations used are leather, asbestos and asbestos tape, neophrene rubber, heat-resisting rubber, rubber and carbon, rubber and asbestos, and cotton tape impregnated with zinc chromate.

17-20. Rubber-based compositions are used for most aircraft seals around access doors. If the seal is near or in contact with high temperatures, use heat-resisting rubber or asbestos. Use asbestos and asbestos tapes as heat barriers.

17-21. A retaining strip is usually placed behind the composition material and riveted. This strip is aluminum alloy or stainless steel and is a means of fastening the seal. Fasten the strip with bolts or bonding cement.

17-22. The best method to follow when repairing or replacing seals is the one given by the manufacturer. Additional information is obtained from the applicable technical order.

17-23. Baffles are used in the air systems of the aircraft to direct and control the flow of air. These baffles are located in heating and cooling ducts, such as the deicer system on the leading edge of the wing, or controlling air system in the crew compartments. Baffles are found on the intake systems of jet engines and also inside the engines to direct the flow of air to the buckets or turbine wheels. They are used on reciprocating engines to guide the flow of air to the spark plugs and cylinders for cooling purposes.

17-24. Baffles are usually made of aluminum so they may be shaped and welded more easily. They are also made of other alloyed metals, and can be riveted and spot welded.

17-25. Repairs are made more easily by following the recommended procedures used by the manufacturer or by consulting the applicable technical order.

17-26. *Control surfaces.* There are many flight control surfaces on modern aircraft. These movable airfoils control the flight of the aircraft. The complicated systems by which the control surfaces function are not the concern of the airframe repairman. Your routine work is directed toward the repair of damaged control surfaces.

17-27. A large part of the trailing edge of most aircraft is composed of conventional control surfaces such as ailerons and flaps. A large part of the empennage is made up of the elevators and rudder. The stabilizers are sometimes referred to as fixed control surfaces. This is considered an erroneous term, for even though fixed vertical and horizontal stabilizers do provide a certain amount of control, the fact that they are not movable excludes them from the control surface group.

17-28. The designing of the latest aircraft is away from conventional control surfaces. Now there are combination control surfaces which obtain the desired performance of jet aircraft. Some of these and the aircraft on which they are found are the F-100 *leading edge movable wing slats;* F-100, and F-101 *stabilator* (one-piece movable horizontal stabilizer); F-102 *elevon* (elevator and aileron combined applicable to delta wing aircraft); F-89 *deceleron* (split aileron acting as both aileron and speed brake): B-47 *flaperon* (aileron and flap combined); and the KC-135 *spoiler-aileron* system (serving as both spoiler and ailerons).

17-29. The larger flight control surfaces consist of ailerons, elevators, flaps, and rudders. The ailerons attached to the trailing edge of the outboard wing sections furnish control about the longitudinal axis for banking. The elevators attached to the trailing edge of the horizontal stabilizer supply control about the horizontal axis for climbing or descending and turning by banking. The rudder gives directional control, while flaps provide additional lift for takeoff and landing.

17-30. There are other, smaller control surfaces, such as trim tabs, balance tabs, and servo tabs. They provide additional stability or control, or help to actuate the larger control surfaces.

17-31. The structural parts of these control surfaces are similar. They usually consist of the following.

17-32. The spar may be of one sheet of aluminum alloy stamped or formed to shape. It may have several holes (lightening holes) which reduce the weight and allow cables or plumbing to pass through. The spar may consist of a web reinforced with beads and formed of extruded cap strips.

17-33. The ribs may be formed from flat sheets stiffened with beads or extrusions, and may also have lightening holes. Ribs provide contour as well as strength.

17-34. Stringers are found on some control surfaces. The skin is attached to them as well as to the ribs. Stringers give stiffness and additional strength.

17-35. Trailing edges may be extruded, formed, or machined, or may consist simply of the skin surfaces riveted together.

17-36. Flaps are usually constructed with skins, spars, and ribs. The skin may cover both surfaces or only the lower surface of the flap.

17-37. *Fairings.* Fairings are auxiliary members that streamline various parts and locations on the aircraft. They reduce drag at that point. They cover the joints formed where wing sections meet the fuselage and where the vertical and horizontal stabilizers mount on the main structure. They are often used to streamline around fittings, navigation lights, landing gear struts, wheels, and the like. Fairings are not strength members and are not intended to carry any of the principal airloads placed on the aircraft structures.

17-38. *Reinforced openings.* Reinforced openings provide access to internal parts of an aircraft and are installed for inspection, maintenance, and repair purposes. The size of a reinforced opening is determined by the space into which it must be installed and the work which must be accomplished through it.

17-39. A reinforced opening consists of two parts: the reinforcing ring and the cover plate. The reinforcing ring is a backing plate which strengthens the opening. The cover plate is flush with the skin and is fastened to the reinforcing ring. If possible, make the opening in an oval shape; the length should follow the direction of stress.

17-40. The material used for the reinforcing ring must be one gage heavier than the skin. Two rows of rivets are generally used around the opening. When space does not permit the use of a complete two-row layout, use one row on the sides and two on the ends. The edge distance, rivet pitch, and transverse pitch, as recommended earlier is most commonly used. The riveting operation is accomplished from one side, with special bucking bars used to buck the rivets.

17-41. Use self-locking units (nut plates) to hold the cover plates. Fasten these units to the reinforcing ring with countersunk rivets. Use any one of the various types. Some units have fiber collars, others have metal collars. The collar is the self-locking part of the nut. Use fiber collars on surfaces exposed to low temperatures, and metal collars for exposure to high temperatures.

17-42. The type of reinforced opening required is usually specified in the -3 technical order for the specific aircraft. If not specified, follow these general rules.

a. Make sure access cannot be obtained through any other opening in adjacent areas.

b. Determine the minimum size opening that will be needed for access to the internal area.

c. Obtain approval of the engineering officer for the layout of the opening.

d. Make the layout for the opening.

e. Trim out the desired area.

f. Fabricate and install the reinforcing ring and cover plate.

17-43. The location of the reinforced opening is an important part of the layout procedures. It should be located on the bottom surface of wings and horizontal stabilizers or on either side of the vertical stabilizer. Also, if possible, use the same type of pattern as the manufacturer used in other similar openings.

17-44. *Stringers.* The skin of the fuselage, wing, and control surfaces is riveted to stringers that act as stiffeners in the construction of the aircraft. Fuselage stringers run longitudinally from the nose of the aircraft to the tail. Some stringers extend the entire distance from the nose to the tail, others extend only a portion of the way. Wing stringers run laterally from the fuselage to the wingtip or a portion of the distance. Control surface stringers usually run the entire length of the control surface.

17-45. Stringers or stiffeners are divided into two groups: those formed by regular forming methods and those that are extruded. Extruded angles are generally used for stringers because of their high strength-to-weight ratio. Extrusions are made by a process similar to the manner in which toothpaste is shaped when forced from a tube. An extruded angle stringer is produced by forcing hot metal through a die in which there is an opening corresponding to the desired cross-section shape of the stringer. The required cross-section shape or area is determined during the design stages of the aircraft by calculating the load the stringer will be required to support.

17-46. Formed stringers are made in numerous shapes by using various forming techniques on brakes or combinations of die presses. When stringers are formed by machine processes, they are made from annealed aluminum alloys and hardened by heat treatment after forming in order to obtain their maximum strength. Regardless of the method of manufacture, most stringers are made of 2024 or 7075 aluminum alloys.

17-47. Damage to stringers usually involves the skin and sometimes the bulkhead or former. The extent of the damage may range from very minor damage to damage so severe that the entire stringer or portion of it has to be removed and replaced. Stringers may fail because of vibration, become weakened by corrosion, or be torn and twisted by collision.

17-48. Stringers are considered as stressed members, whether located in the fuselage, the wing, or a control surface. The location of the stringer determines the amount of stress to which it is subjected and, therefore, the type of repair that must be made. General rules to follow in all repair procedures are:

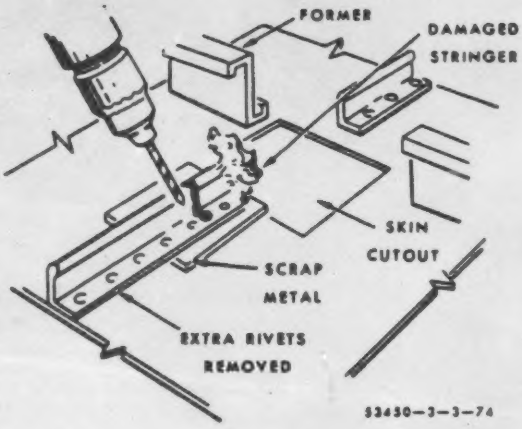


Figure 74. Scrap metal under stringer repair.

a. Design the repair to be equal in strength to the original member.

b. Use the same type of material as that in the original member.

c. Use the same type and size of rivets.

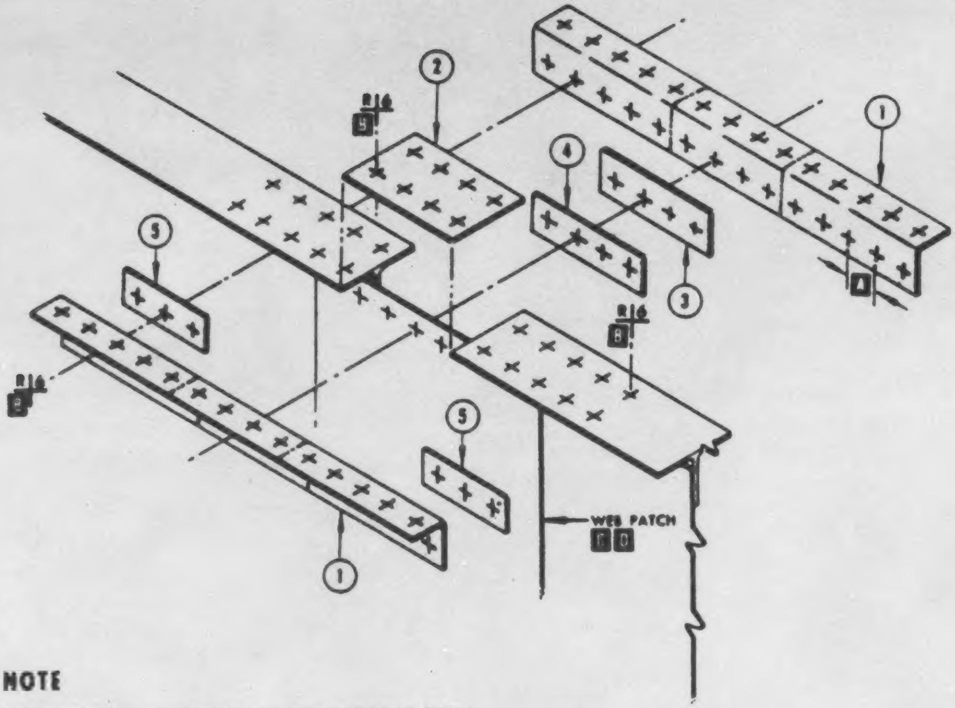
d. Use the same rivet pattern as that used to attach the original member whenever possible.

17-49. Stringer repairs are primarily dependent on three things: (1) location of the stringer in the aircraft, (2) location of damage to the stringer, and (3) extent of damage to the stringer.

17-50. When making a stringer repair, the first step is to survey the damage. Once you determine the amount and extent of damage, consult the appropriate –3 technical manual for detailed information on the correct procedures and methods to follow in the accomplishment of the repair. After locating and studying the information in the technical manual, remove the rivets from the area surrounding the damage. Then remove the damaged area of the stringer by the use of a hacksaw, keyhole saw, drill, or file. Never attempt to remove the damaged area of the stringer until you place a piece of scrap metal under the stringer to prevent damage to the adjacent skin or members, as illustrated in figure 74.

17-51. When removing the damaged stringer section, you will find it best to cut each end midway between the center of two rivets so that rivet continuity can be maintained in the repair. After you cut out the damaged stringer section, file each end of the stringer smooth.

17-52. Since most stringer repairs require the use of an insert and splice angle, observe the following precautions:


②
R16
B
④
①
⑤
③
A
R16
B
R16
B
⑤
WEB PATCH
C D
①

NOTE

A USE ORIGINAL SPACING WHERE APPLICABLE OR SELECT A SPACING BETWEEN .60 AND 1.50

B USE UNIVERSAL HEAD RIVETS UNLESS ORIGINAL RIVETS WERE FLUSH

C SEE FIGURE 10-2 FOR WEB REPAIR

D WHERE WEB PATCH MUST BE PLACED ON SAME SIDE OF WEB AS TEE, MAKE REPAIR AS SHOWN IN FIGURE 4-17. USE RIVETS AND REPAIR MATERIALS CALLED FOR IN THIS REPAIR

REPAIR MATERIAL

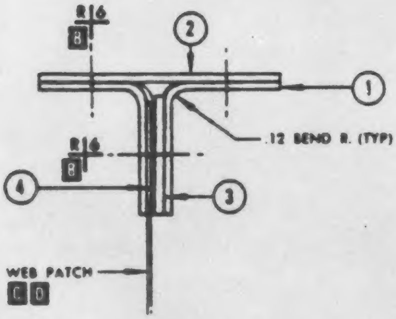
① 2 SPLICE ANGLES
.071 CLAD 7075-0, HT TR-T6

② 1 CHORD FILLER
.063 CLAD, 7075-T6

③ 1 CHORD FILLER
.063 CLAD, 7075-T6

④ 1 WEB FILLER
CLAD 7075-T6, SELECT GAGE TO SUIT

⑤ 2 FILLERS
CLAD 7075-T6, SELECT GAGE TO SUIT


R16
B
②
①
.12 BEND R. (TYP)
R16
B
④
③
WEB PATCH
C D

SECTION THROUGH DAMAGE

53450-3-3-75

Figure 75. Extruded member repair.

a. To avoid bad loading and buckling in compression, space the splicing or reinforcing members as evenly as possible about the center of the part being repaired.

b. When possible, use two rows of staggered rivets to prevent reducing the strength of the stringer in tension.

c. When you splice several adjacent stringers, stagger the splices. This prevents the splices being directly opposite each other and insures the spread of stress concentration.

d. If the stringer damage occurs close to a bulkhead or former, cut the damaged stringer so that only the insert extends through the opening in the bulkhead. If the opening is enlarged to accommodate both the insert and the splice angle, the bulkhead is weakened. When damage of this type occurs, use two splices for the repair.

17-53. Now that we have discussed some of the generalities concerning stringer or stiffener repair, let's discuss a typical extruded member repair in more detail.

17-54. Assume that an extruded section has been damaged. The first step is to locate an illustration of a similar repair in the applicable -3 technical manual. Figure 75 is a reproduction of a page from a technical manual and illustrates a repair to an extruded section. Study it thoroughly before proceeding further. You will find that it gives you information on the method to use in making the repair, type and location of the rivets, and the correct material and method to use in making the repair pieces.

17-55. After studying the illustration to determine proper repair procedures, remove the rivets from the angle in the area next to the damage. After the rivets have been removed, trim the damaged extruded section and square and smooth the remaining ends. Trim the damage halfway between the end rivets of the area to be removed. Ordinarily, use the same rivet pitch as that used for any existing rivets in the repair.

17-56. Repair material, in figure 75, gives you the type of material and number of pieces needed for the repair. Under "Note," you will find information as to the type and spacing of the rivets or fasteners to be used in repair.

17-57. Using the information from the illustration, prepare and position the repair pieces in the repair area and mark and drill the rivet locations. Follow the rivet pattern given in the illustration. After the holes have been drilled, remove all burrs and apply a corrosion preventive compound to faying surfaces if applicable.

17-58. After reinstallation of the parts in the repair area, select and install rivets of the correct length to form the proper shop head. Shave the manufactured heads of countersunk rivets to the tolerance given in the technical manual of structural repair for the specific aircraft.

17-59. *Bulkheads.* Bulkheads are the oval-shaped members of a monocoque or semimonocoque fuselage which give form to and maintain the shape of the structure. In addition, bulkheads are sometimes called formers, forming rings, body frames, circumferential rings, belt frames, and other descriptive names. They carry concentrated stress loads. There are various types of bulkheads, but the most common type is a curved channel formed from sheet stock with stiffeners added. Others consist of a web made from sheet stock with extruded angles riveted in place as stiffeners and flanges. Most of these members are made from aluminum alloys; however, corrosion-resistant steel formers are used in areas exposed to high temperatures. Bulkheads are identified by station numbers, which are helpful in locating repair information for a specific bulkhead.

17-60. Repairs to these members generally ran into two types. If one-third or less of the cross-sectional area has been damaged, a patch plate and a reinforcing angle, or both, are used in the repair procedures. The damage is cleaned out and the rivet formula used to determine the number of rivets required for the repair. Rivet spacing will establish the size of the patch plate. The length of break is determined by measuring the depth of the cutout and adding the width of the flange.

17-61. If more than one-third of the cross-sectional area is damaged, remove the entire section and make a splice repair in the area. When removing the damaged area, be careful to keep from damaging surrounding equipment (electrical lines, plumbing lines, instruments, etc.). To remove the damaged area, use a hand file, rotary file, snips, drill, hacksaw, or keyhole saw. Determine the length of break by measuring the width of the bulkhead and both of the flanges. Use the double shear value of the rivet in calculating the number of rivets required for the repair. The result of your calculations will be the number of rivets required for each end of the splice plate.

17-62. Most repairs to bulkheads are made from flat sheet stock when spare parts are not available. When fabricating the repair from flat sheet, observe the following rules:

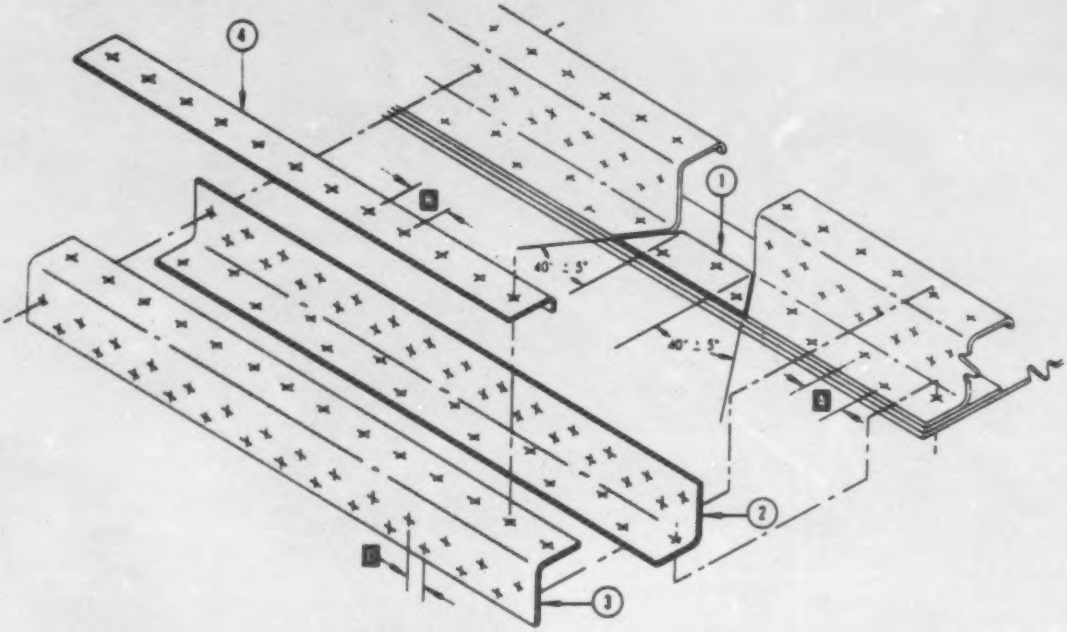
a. The substitute material must provide cross-sectional strength in tension, compression, shear, and bearing.

b. Never use material which is thinner than or has a cross-sectional area less than the original member.

c. Curved repair parts made from flat sheet stock must be in an annealed condition before forming; it then must be heat-treated to the specified temper after forming and before installation.

17-63. With these general rules to follow, use the specific procedures outlined in the appropriate -3 technical manual to make required repairs.

17-64. *Longerons.* Generally, longerons are comparatively heavy members which serve approximately the same purpose as stringers. Since the primary difference between longerons and stringers is size and weight, longeron repair procedures are similar to stringer repair procedures. Be-



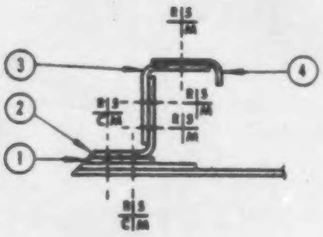
REPAIR MATERIAL

① 1 FILLER
.040 AISI TYPE 17-7PH CRES,
HT TR 180,000 TO 200,000 PSI

② 1 ANGLE
.032 AISI TYPE 17-7PH CRES,
HT TR 180,000 TO 200,000 PSI

③ 1 ANGLE
.032 AISI TYPE 17-7PH CRES,
HT TR 180,000 TO 200,000 PSI

④ 1 ANGLE STRAP
.032 AISI TYPE 17-7PH CRES,
HT TR 180,000 TO 200,000 PSI



SECTION THROUGH REPAIR

NOTE

THIS REPAIR APPLICABLE TO UPPER LONGERON AFT OF STATION 171.82

FOR SKIN REPAIR SEE FIGURE 10-1

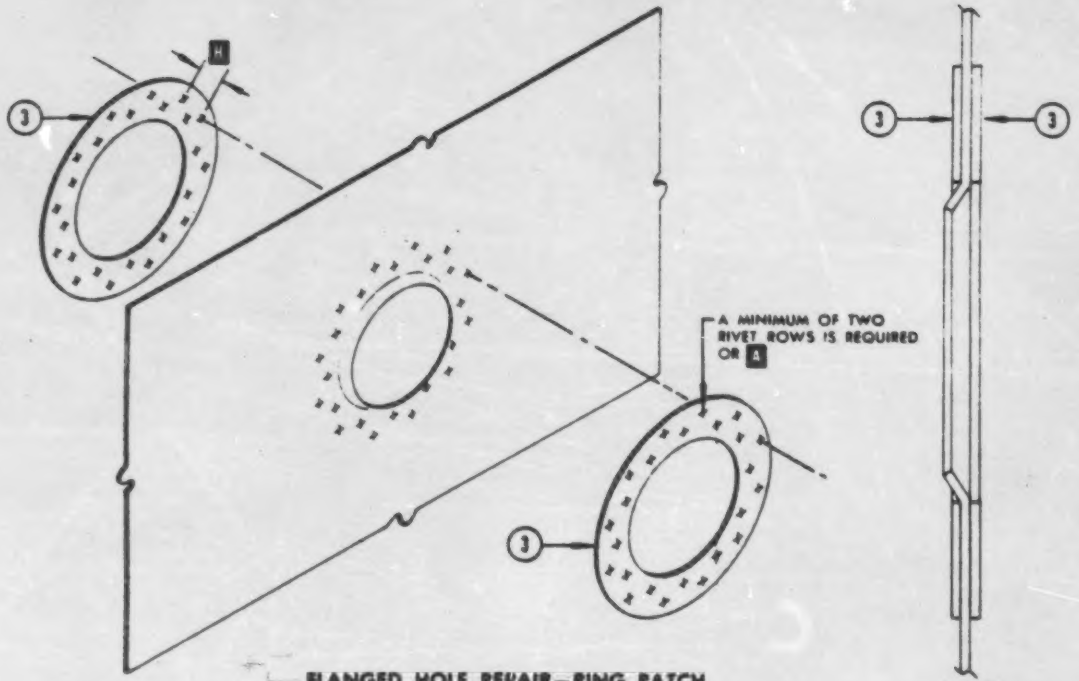
■ ORIGINAL SPACING

■ MATCH ORIGINAL SPACING

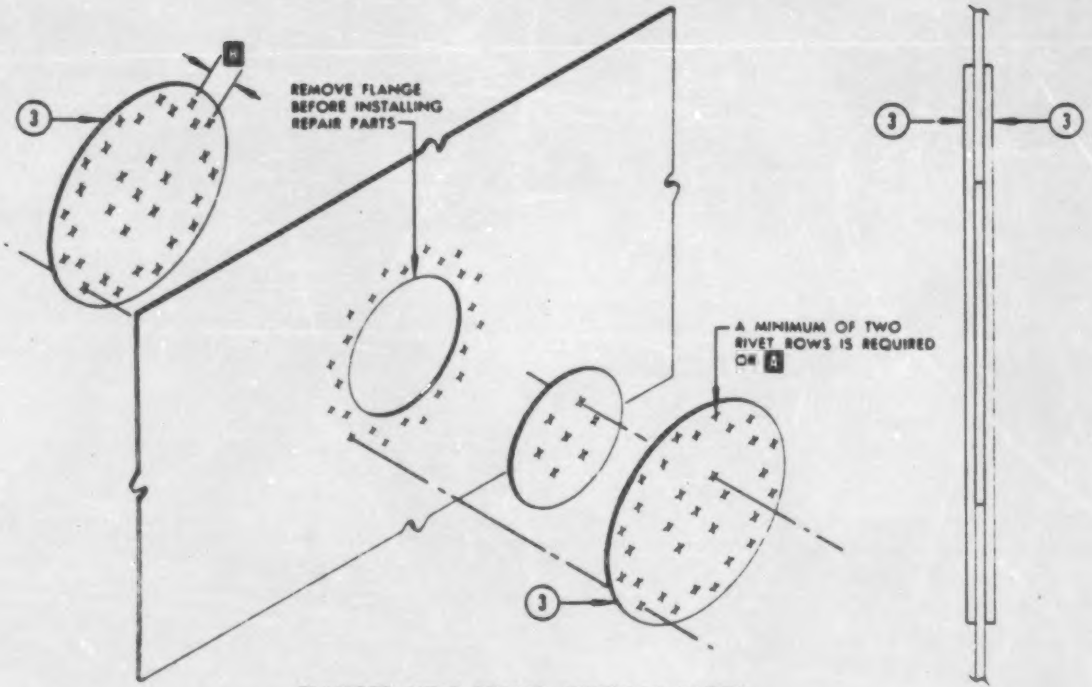
■ USE ONE-HALF ORIGINAL SPACING

53430-3-3-76

Figure 76. Longeron repair.


H
3
3
3
A MINIMUM OF TWO RIVET ROWS IS REQUIRED OR A
3

FLANGED HOLE REPAIR—RING PATCH


H
REMOVE FLANGE BEFORE INSTALLING REPAIR PARTS
3
3
3
A MINIMUM OF TWO RIVET ROWS IS REQUIRED OR A
3
53450—3—3—77

FLANGED HOLE REPAIR—CIRCULAR PATCH

Figure 77. Typical web repair.

356

TABLE 14

FASTENERS FOR WEB REPAIR

GAGE		RIVETED MATERIAL															
		2024-T3								7075-T6							
		TYPE OF FASTENERS								TYPE OF FASTENERS							
		MS20470					HS52P			MS20470					HS52P		
		1/8	5/32	3/16	1/4	5/16	3/16	1/4	5/16	1/8	5/32	3/16	1/4	5/16	3/16	1/4	5/16
.020	A REQD ROWS B MIN MAX									1 .41 .59	1 .51 .74						
.022	A REQ'D ROWS B MIN MAX									1 .41 .57	1 .51 .72						
.025	A REQ'D ROWS B MIN MAX	1 .43 .38								1 .41 .36	1 .51 .70						
.028	A REQ'D ROWS B MIN MAX	1 .43 .34								1 .41 .35	1 .51 .67						
.032	A REQ'D ROWS B MIN MAX	1 .43 .53	1 .54 .66							1 .41 .53	1 .51 .66	1 .62 .80					
.036	A REQ'D ROWS B MIN MAX	1 .43 .51	1 .54 .63							1 .41 .45	1 .51 .63	1 .62 .77					
.040	A REQ'D ROWS B MIN MAX	1 .43 .46	1 .54 .61	1 .65 .74						2 .41 .80	1 .51 .62	1 .62 .75	1 .82 1.00				
.045	A REQ'D ROWS B MIN MAX	2 .40 .80	1 .54 .60	1 .65 .72						2 .41 .68	1 .51 .52	1 .62 .77	1 .82 1.00				
.050	A REQ'D ROWS B MIN MAX	2 .43 .70	1 .54 .55	1 .65 .70	1 .86 .94					2 .41 .38	2 .51 .92	1 .62 .66	1 .82 .89				
.056	A REQ'D ROWS B MIN MAX	2 .43 .60	2 .54 .94	1 .65 .67	1 .86 .90							2 .62 1.14	1 .82 .89		1 .62 .69	1 .82 .84	
.063	A REQ'D ROWS B MIN MAX	2 .43 .57	2 .54 .80	2 .65 1.15	1 .86 .88	1 1.07 1.09						2 .62 .94	1 .82 .84	1 1.02 1.05	1 .62 .64	1 .82 .86	
.071	A REQ'D ROWS B MIN MAX		2 .54 .70	2 .65 1.00	2 .86 1.70	2 1.07 1.07	2 .65 1.28					2 .62 .82	2 .82 1.48	1 1.02 1.04	2 .62 1.24	1 .82 1.18	
.080	A REQ'D ROWS B MIN MAX		2 .54 .60	2 .65 .86	2 .86 1.50	2 1.07 2.04	2 .65 1.22	2 .86 1.62				2 .62 .70	1 .82 1.27	2 1.02 1.96	2 .62 1.20	1 .82 1.24	
.090	A REQ'D ROWS B MIN MAX			2 .65 .72	2 .86 1.30	2 1.07 1.96	2 .65 1.16	2 .86 1.58				2 .62 .62	2 .82 1.18	2 1.02 1.70	2 .62 1.17	1 .82 1.27	
.100	A REQ'D ROWS B MIN MAX			3 .89 1.05	2 1.17 1.25	2 1.47 1.92	2 .89 1.25	2 1.17 1.60	2 1.47 2.08				3 1.34 1.47	3 1.68 2.20	2 1.02 1.04	2 1.34 1.34	2 1.68 1.82
.112	A REQ'D ROWS B MIN MAX			3 .89 .94	3 1.17 1.67	2 1.47 1.74	2 .89 1.25	2 1.17 1.67	2 1.47 2.08				3 1.34 1.34	3 1.68 2.30	3 1.02 1.46	2 1.34 1.34	2 1.68 1.82
.125	A REQ'D ROWS B MIN MAX				3 1.17 1.50	2 1.47 1.56	2 .89 1.22	2 1.17 1.67	2 1.47 2.08					3 1.68 1.64	3 1.02 1.49	2 1.34 1.34	2 1.68 1.70
.140	A REQ'D ROWS B MIN MAX				3 1.17 1.24	3 1.47 2.08	2 .89 1.25	2 1.17 1.67	2 1.47 2.08						3 1.02 1.60	2 1.34 1.37	2 1.68 1.70
.160	A REQ'D ROWS B MIN MAX				3 1.17 1.17	3 1.47 1.82	2 .89 1.19	2 1.17 1.68	2 1.47 2.08						3 1.02 1.40	2 1.34 1.46	2 1.68 1.73
.180	A REQ'D ROWS B MIN MAX					3 1.47 1.62	2 .89 1.06	2 1.17 1.68	2 1.47 2.08						3 1.02 1.25	2 1.34 1.47	2 1.68 1.75
.190	A REQ'D ROWS B MIN MAX					3 1.47 1.54	2 .89 1.00	2 1.17 1.68	2 1.47 2.08						3 1.02 1.18	2 1.34 1.40	2 1.68 1.78
.200	A REQ'D ROWS B MIN MAX						2 .89 .95	2 1.17 1.67	2 1.47 2.08						3 1.02 1.12	2 1.34 1.34	2 1.68 1.82
.224	A REQ'D ROWS B MIN MAX						3 .89 1.27	2 1.17 1.31	2 1.47 2.08							3 1.34 1.78	2 1.68 1.85
.250	A REQ'D ROWS B MIN MAX						3 .89 1.10	2 1.17 1.34	2 1.47 2.08							3 1.34 1.60	3 1.68 2.30

33459-3-3-T16

cause the longeron member is a heavy member and because more strength is needed than with a stringer, use larger rivets and heavier material to make the repair. Very often, Hi-Shear rivets are used in longeron repair instead of regular rivets. In this case, greater accuracy in drilling and reaming of holes is required and more time is consumed in installation.

17-65. Figure 76 illustrates a typical longeron repair. Study the figure for procedures and materials, and note the similarity of methods used here and those discussed for the repair of an extruded stiffener.

17-66. *Spars.* Spars are the chief supporting members of the other components of wings and stabilizers. Think of spars as the "cornerstone," since they are usually the first members of a section to be installed. The remaining components are fastened directly or indirectly to them. Because of the load that spars carry, be careful not to weaken them when you repair them. Spars are generally constructed so that two distinct kinds of repairs can be made: web repairs and cap strip repairs. Damages may require the use of either one or both of these repairs.

17-67. What are some of the procedures to be followed in the repair of a damaged spar? First, as in other cases, search the applicable –3 technical manual for the specific aircraft and locate a typical repair illustration. Figure 77 illustrates the methods and procedures to be followed in the typical repair of damage to a spar web. Table 14 lists the type, number of rows, and spacing for fasteners in various web thicknesses.

17-68. Be sure that you follow all technical manual procedures in preparation for making the repair. In some instances, jacking or reinforcement of a wing may be necessary. Access to damages can be gained usually through access doors in the immediate vicinity of the damage. You must be extremely careful to prevent damage to control cables, fuel cells, actuators, and other components that are located in the area of the damage. If any of these components must be removed so that you may do your work, get assistance from personnel responsible for maintaining these components.

17-69. The information given in figure 76 and table 14 will enable you to figure the size of the patch, number of rivets to use, and their location in the repair area. It is best to make a paper layout of the area first and then transfer this pattern to the metal to be used in the repair. After the patch has been prepared and the metal freed from burrs, install the patch in the proper position and rivet it in place.

17-70. A discussion of cap strip repairs will not be given here, since repair of these members is usually limited to repair of the flanges. Ordinarily, damages more extensive than small cracks or dents in the flanges or cap strips necessitates replacement of the entire cap strip.

17-71. *Ribs.* Ribs provide shape and rigidity to the wings and stabilizers. They resist compression as well as shear loads. In addition, ribs pass along loads from the skin to the spars. Ribs are usually of three types: trussed rib, solid web, and lightening hole. As trussed type ribs are very seldom used and the repair of a solid web type is very similar to the repair of a web, we will discuss only the repair of the lightening hole type.

17-72. Again, the first step is to locate and read pertinent instructions found in the applicable –3 technical manual. Figure 78 is a reproduction of a technical manual page and illustrates the procedures to follow in the repair of a wing flap rib. Study the illustration for the type of material to use in the repair and the type and location of the fasteners. When making any repair, the rule is *always follow the instructions.*

17-73. After studying the instructions, remove the damaged area. Prepare the parts to be inserted in the repair area, place them in position, and mark rivet locations. Drill holes, clean parts of burrs, and rivet the parts in place. It all sounds very simple when you are reading about it, but the results are determined by the care you exercise in the preparation and installation of the repair parts.

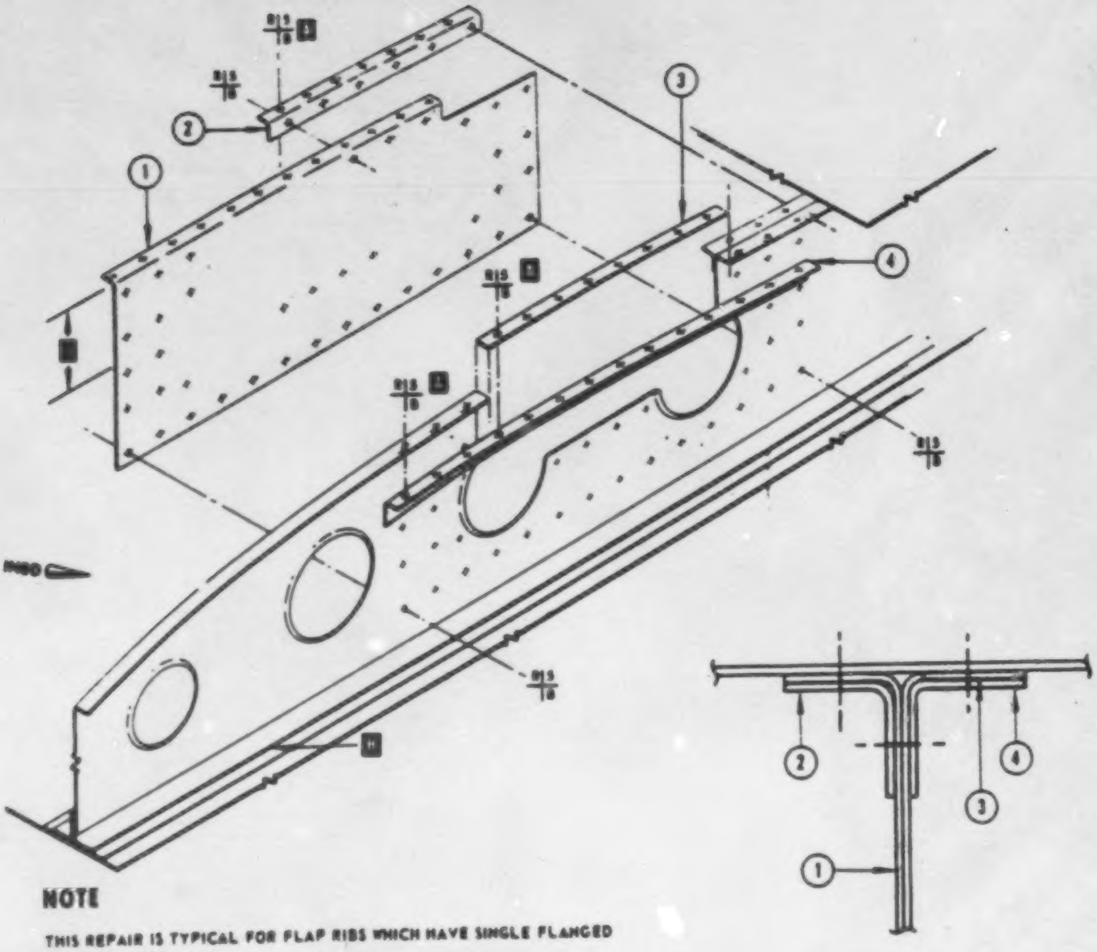
17-74. *Leading edges.* The leading edge is the front section of a wing or stabilizer. The purpose of the leading edge is to streamline the forward section of the member. The space within the leading edge is sometimes used to store fuel. This space may also be used to house extra equipment, such as landing lights, plumbing lines, or thermal anti-icing systems.

17-75. Construction of the leading edge section varies with the type of aircraft for which it is designed. Since it is so varied, we will not discuss a typical repair here but will give you only general information about repair procedures. Generally, the structure will consist of cap strips, nose ribs, stringer, and skin.

17-76. The cap strips are the main lengthwise extrusions. Cap strips serve to stiffen the leading edges and provide a base for the nose ribs and skin. They also provide a means of fastening the leading edge to the front spar.

17-77. The nose ribs are stamped from aluminum alloy sheet. These ribs are U-shaped and may or may not have their web sections stiffened. Regardless of their design, their purpose is to provide contour to the leading edge.

17-78. Stiffeners are used to stiffen the leading edge and to supply a base for fastening the nose skin. Only flush rivets are used to attach the nose skin.



NOTE

THIS REPAIR IS TYPICAL FOR FLAP RIBS WHICH HAVE SINGLE FLANGED UPPER CHORDS

THIS REPAIR APPLIES AFT OF FLAP SPAR AS WELL AS FORWARD AS SHOWN

IN BLIND AREAS USE BLIND STEEL FASTENERS IN LIEU OF RIVETS INDICATED

FOR SKIN REPAIR SEE FIGURE 10-1

WHEN DAMAGE AFT OF AUXILIARY SPAR IS CONSIDERED EXTENSIVE, REPLACE RIB. IF SPARE PART IS NOT AVAILABLE, FORM NEW RIB USING ONE GAGE HEAVIER THAN ORIGINAL. WHEN DAMAGE FORWARD OF AUXILIARY SPAR IS CONSIDERED EXTENSIVE, REPAIR AS SHOWN IN FIGURE 2-60A

WHERE STIFFENERS ARE USED ON RIB, REMOVE ORIGINAL STIFFENER AND REPLACE WITH NEW STIFFENER JOGGLED TO CLEAR PART 4

A CSK UPPER SURFACE AFT OF AUXILIARY SPAR

B FOR REPAIR OF LOWER FLANGE SEE PARAGRAPH 10-72

C FOR REPAIR OF CRACKS IN BEND OF RIB FLANGE, REDUCE PATCH DEPTH TO THIS DIMENSION. INSTALL MINIMUM OF TWO ROWS OF RIVETS BELOW CRACK AND INSTALL MINIMUM OF THREE FASTENERS PER ROW FROM EACH EXTREMITY OF CRACK

SECTION THROUGH DAMAGE

REPAIR MATERIAL

① 1 ANGLE
.063 CLAD 2024-0 HT TR-T4

② 1 ANGLE
.063 CLAD 2024-0 HT TR-T4

③ 1 FILLER
GAGE OF ORIGINAL RIB
CLAD 2024-T4

④ 1 ANGLE
.063 CLAD 2024-0 HT TR-T4

53430—3—3—78

Figure 78. Wing flap rib repair.

17-79. Leading edges constructed with thermal anti-icing systems consist of two layers of skin separated by a thin airspace. The inner skin, sometimes corrugated for strength, is perforated to conduct hot air to the nose skin for anti-icing purposes.

17-80. Damages encountered on leading edges are caused by contact with other objects, such as flying objects, flak, pebbles, birds, etc. However, the major cause of leading edge damage occurs through carelessness of maintenance personnel while the aircraft is on the ground.

17-81. A damaged leading edge usually involves several structural parts. For example, flying object damage probably includes the nose skin, nose ribs, stringers, and possibly the cap strip. A damage involving all of these members probably necessitates an access door to make repair possible. First, the damaged area has to be removed and repair procedures established. The damage probably requires insertions and splice pieces. If the damage is serious enough, it might require repair of the cap strip and stringer, a new nose rib, and a new skin panel. When repairing a leading edge, you must follow to the letter the procedures established for the repair in the appropriate technical manual or structural repair manual.

17-82. *Trailing edges.* A trailing edge is the rearmost part of an airfoil—a wing aileron, rudder, elevator, or stabilizer. Generally a metal strip forms the shape of the edge by tying the ends of a rib section together and joining the upper and lower skins. Although trailing edges are not designed to give added strength to the structure, they are considered as being stressed in all cases.

17-83. Trailing edges are constructed in many different ways and are covered with either metal or fabric. The use of fabric for covering airfoils is mostly confined to light aircraft. For this reason we will not attempt to discuss typical repairs; however, we will discuss some of the various designs and general procedures used in repairing them.

17-84. The rod type of trailing edge is generally used on small, fabric-covered control surfaces. Damaged sections of the rod must be replaced from wing rib to wing rib and fastened in place with metal clips.

17-85. Tubing is used in place of a rod for a trailing edge in larger fabric-covered control surfaces. This edge can best be repaired by inserting a solid reinforcement splice and riveting the original tubing to it. The tubing may be spread at the break, or part of its surface may be cut away in order to insert the splice.

17-86. A small plane with correspondingly small wings and control surfaces might use a solid bar to give the trailing edge its required stiffness. These bars are used in airfoils which are covered with metal skin and are repaired by simply fastening a reinforcement splice or patch of sheet stock over the crack.

17-87. An overlapped skin trailing edge is found on some metal-covered airfoils. In such cases, the upper and lower skin surfaces are overlapped sufficiently to permit them to be riveted together. You may repair this type of trailing edge by using a reinforcement patch of sheet stock which is joggled to conform to the contour of the overlapping skins. The channel type is one of the most commonly used trailing edges in both metal and fabric-covered airfoils.

17-88. Damage to trailing edges of wings, control surfaces, or flaps may be limited to one point or may extend over an entire length between two or more rib sections. Damage caused by gunfire, collision, ground looping, or careless handling results in buckling, cracking, or holes. Corrosion is not always apparent, but remember that trailing edges are particularly subject to it. Moisture tends to be trapped in the trailing edge of the wing when the drainage holes become clogged.

17-89. You must make a thorough inspection of the damaged area to determine the extent of the damage, type of repair to be made, and manner in which it should be performed.

17-90. If the damage constitutes a crack or break in the trailing edge, it may be restored to its original strength with a reinforcement splice or patch. The shape and type of reinforcement will be determined by whether the airfoil is covered by metal or fabric. When the reinforcement is to be made from an extrusion, it should be of the same contour and temper as the original in order to restore the initial strength. For trailing edges with a small radius, the splice may be most easily made of solid material, such as aluminum alloys, Micarta, or Bakelite.

17-91. In cases where the reinforcement must be made of sheet stock, it should be one gage heavier than the original member, of the same temper, and formed to fit the original.

17-92. Damage to a trailing edge may be extended over such an area that a section of it must be removed and replaced. In this case, the new section must be of size, shape, and temper to duplicate the original. It may be an extruded shape, or it may be formed from sheet stock, depending upon the available material.

17-93. The actual procedures for making the repairs just described are so lengthy that they are not discussed here; however, you should have a general idea of the procedures involved. Always consult the appropriate technical manual of structural repair before attempting any repair.

18. Structural Sealing

18-1. Certain areas of airframe structures are sealed compartments where fuels or air must be confined. Some of these areas contain fuel tanks; others consist of pressurized compartments such as the cockpit. Since it is impossible to seal these areas completely airtight or watertight with a riveted joint alone, a sealing compound or sealant is used. Sealants are also used to add aerodynamic smoothness to external surfaces at seams and joints.

18-2. Three types of seals are ordinarily used. Rubber seals are installed at all points where frequent breaking of the seal is necessary (such as canopies and access doors). Sealing compounds are used only for structural maintenance and part replacement at points where the seal is broken, such as riveted lap and butt seams. Special seals are required for passing cables, tubing, mechanical linkages, and wires out of pressurized or sealed areas.

18-3. Wires and tubes are passed through pressure bulkheads by using bulkhead fittings such as cannon plugs for wiring and couplings for tubing. These fittings are sealed to the bulkhead and the wires and tubes are fastened to them from each side. All seals of moving components, such as flight controls, are subject to wear. Install them carefully and check them regularly.

18-4. **Classification of Sealing Levels.** The four types of sealing levels are as follows:

a. Absolute sealing. An absolute seal is obtained when a compartment is sealed tight enough to permit no leakage. It requires the sealing of all seams, holes, slots, joggles, and structures which are fastened to the seal plane. All fasteners must be sealed if the seal is to be absolute.

b. Extensive sealing. An extensive seal is obtained when all holes, slots, joggles, and seams in the seal plane are sealed. Sealing is required for all bolts, screws, blind rivets, and repair rivets except (1) protruding rivets, (2) standard flush rivets in dimpled holes, (3) standard flush rivets in countersunk holes if driven high and shaved, or (4) upset heads of dural rivets.

c. Intermediate sealing. An intermediate seal is obtained when all holes, joggles, seams, and slots in the seal plane are sealed. Fasteners do not require sealing.

d. Limited sealing. A limited seal is obtained when all holes, slots, and joggles in the seal plane are sealed. Seams and fasteners do not require sealing.

18-5. **Environmental Sealing Types.** Sealing is further grouped according to the type of environment. Eight types are described in the following paragraphs. Each of the types may be placed in one of the four sealing classification levels.

18-6. *Fuel sealing.* Fuel sealing is used to confine or control either liquid fuel or fuel vapor within a defined area. In a fuel-sealed area, the sealant must be fuel resistant. Liquid fuel sealing falls in the absolute sealing classification. Fuel vapor sealing is classified as intermediate sealing.

18-7. *Pressurized area sealing.* Pressure sealing is used to maintain a required pressure within a defined area. This is an allowable leakage type of sealing; however, proper application of sealants should keep leakage small enough that correct cabin pressure can be maintained at high altitude. Cabin area sealing falls into the extensive sealing classification. Aerodynamic balance sealing of the empennage is classed as limited sealing. Aerodynamic sealing areas in the wing are classified as intermediate sealing. In pressure sealed areas, the sealant is always applied to the pressure side of structure.

18-8. *Weather sealing.* Weather sealing is used to insure adequate protection from moisture, dust, and rain, and generally falls in the intermediate level. The entire exterior surface of the aircraft is sealed by application of aerodynamic smoother which is applied to all skin joints and fasteners; however, various compartments and doors, particularly along the upper fuselage surface, are sealed internally.

18-9. *Firewall sealing.* Firewall sealing is used to restrict the passage of flames through the seal plane. This type is classified absolute, intermediate, and limited, according to the area where it is used. Materials used for this type of sealing are exceedingly critical.

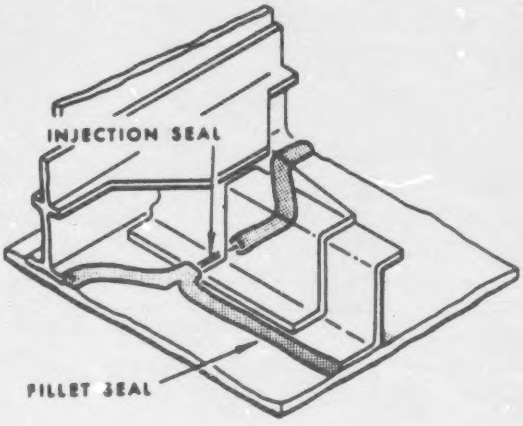


Figure 79. Typical fillet seal.

18-10. *Electrical sealing*. Electrical sealing is used to prevent leakage of fuel, fuel vapor, or pressurized air from a sealed area; to prevent fuel or fuel vapor from entering connectors and compartments where arcing might occur; and to prevent dust and water from entering connectors and electrical components, thus causing corrosion. Materials used for this type of sealing are dependent upon the environmental location of the seal.

18-11. *Acid-resistant sealing*. Acid-resistant sealing and acid-resistant finishes are used to prevent any corrosive solution of battery electrolyte or uric acid from contacting the structure. Acid sealing is classified as absolute sealing.

18-12. *Window sealing*. Window sealing is a combination of pressure sealing, weather sealing, and aerodynamic smoothing.

18-13. *High-temperature sealing*. High-temperature sealants must be used in those areas where operating temperatures exceed 93° C. (200° F.). These include engine pods, antiicing ducts and adjacent structure, engine air bleed lines to air-conditioning turbines, and areas adjacent to various electronic equipment.

18-14. **Sealing Terms.** The following is made up of defined terms which are used to describe materials and procedures for maintaining general aircraft sealing:

Sealant—Mixture of base compound and accelerator which will cure to a firm fuel-, acid-, or water-resistant material.

Accelerator—Internal curing agent for sealants.

Base Compound—The major component of sealant material used with accelerator to produce a fuel-, acid-, or water-resistant sealant.

Seal Plane—The interior surfaces of a tank, tank cavity, or pressurized compartment (comprised of structure, integrally sealed fasteners, and sealant) which actually contains the liquid or pressurized air.

Primary Seal—Sealant applied to structure which becomes a part of the seal plane.

Secondary Seal—Sealant applied behind and in conjunction with primary sealing to confine liquid or pressurized air.

Backup Seal—A secondary seal which supports a primary seal.

Repair Seal—A seal placed for the purpose of limiting the amount of sealing required to repair a leak.

Faying Surface Seal—A seal effected by the sandwiching of sealant between mating surfaces of assemblies.

Injection Seal—Filling of holes or channels by forcing sealant into a void or cavity to obtain a primary or backup seal.

Fillet—A bead of sealant applied along structural junctions or seams.

Re-Entrant Fillet—An overlapping quantity of sealant not in close contact with adjacent sealant or structure.

Top Coat—A continuous film of material which provides sealant protection from fuel and corrosion protection for metal surfaces.

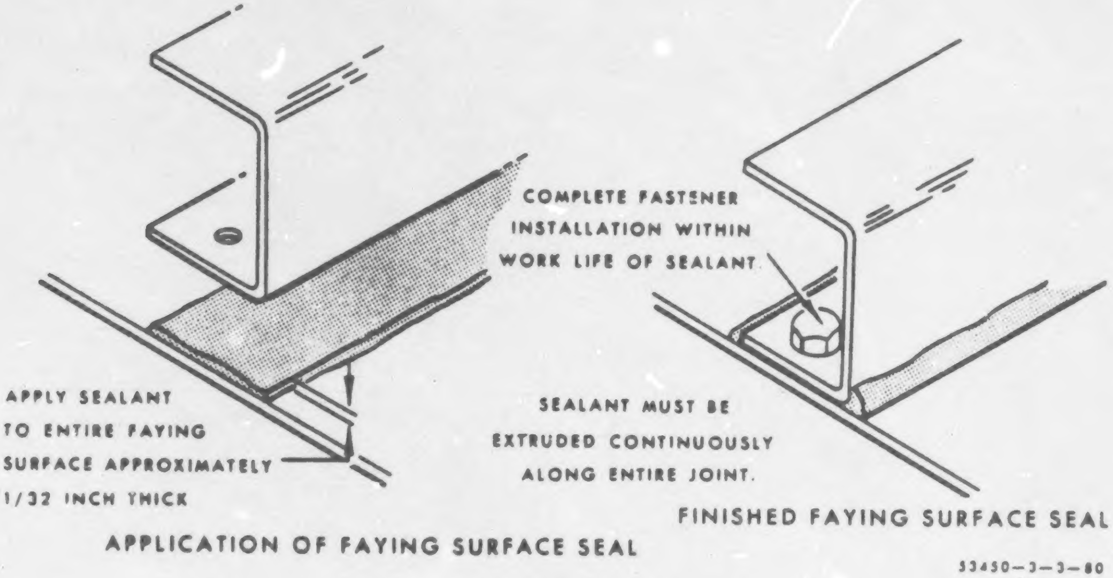

COMPLETE FASTENER INSTALLATION WITHIN WORK LIFE OF SEALANT
APPLY SEALANT TO ENTIRE FAYING SURFACE APPROXIMATELY 1/32 INCH THICK
SEALANT MUST BE EXTRUDED CONTINUOUSLY ALONG ENTIRE JOINT.
FINISHED FAYING SURFACE SEAL
APPLICATION OF FAYING SURFACE SEAL
53450-3-3-80

Figure 80. Faying surface seal.

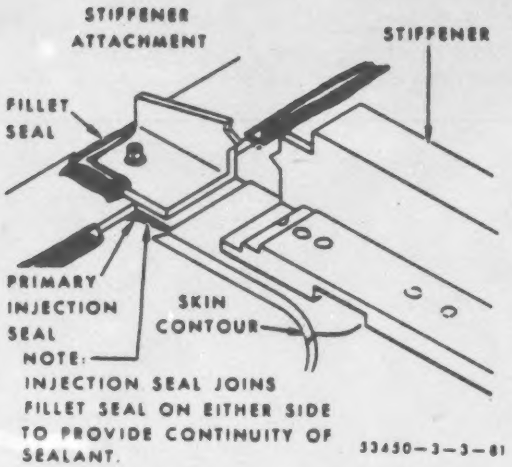

STIFFENER ATTACHMENT
STIFFENER
FILLET SEAL
PRIMARY INJECTION SEAL
SKIN CONTOUR
NOTE: INJECTION SEAL JOINS FILLET SEAL ON EITHER SIDE TO PROVIDE CONTINUITY OF SEALANT.
33430—3—3—81

Figure 81. Typical injection seal.

Tack-Free Time—That point of time in the curing of a sealant or top coat at which the material does not stick when a dry knuckle is pressed lightly against the sealant or top coat and withdrawn.

18-15. **Typical Sealant Installations.** There are various types of seals used to produce a sealed area. Each of these types has a definite place where it is to be used. The following paragraphs contain a description of these types and tells where they are used.

18-16. *Fillet sealing.* The fillet, or seam seal (see fig. 79), is a primary seal and the most common type found on an aircraft. Fillet seals are used to cover structural joints along stiffeners, skin butts, walls, spars, and longerons and to seal around fittings and fasteners. This type is the most easily repaired and the most efficient seal that can be produced.

18-17. *Faying surface sealing.* This type of seal (see fig. 80) is applied between the contacting surfaces of two or more parts. In some instances, this type is used to produce a block-off seal, to effect a seal between parts where a fillet seal would mean extensive sealing, and where the assembly sequence restricts the use of fillet seals. There are two types of faying surface seals: removable and permanent. The removable type is used around access doors, removable panels, inspection plates, windows, etc. The permanent type is used between parts of a structure that is permanently fastened together.

18-18. *Injection seals.* This type of seal (see fig. 81) is primarily used to produce continuity between seals. When fillet seals reach a point where they can no longer be applied in a continuous line, an injection seal is used to produce this continuity. This seal goes through joggles, gaps, openings, etc. It is also used where the structure is so designed that the compound has to be forced into an area to make contact with certain parts.

18-19. **Sealant Defects.** Pressure tightness of an area or section is checked before and after a repair is made. Ground pressurization is accomplished by filling the section with air from an external source through ground pressure testing fittings.

18-20. With the section pressurized to a given pressure, leaks may be located on the outside of the aircraft by applying a soapless bubble fluid to all joints and seams in the suspected area. Air bubbles will locate the general area of the leakage. A specific leak is then isolated on the inside of the aircraft by passing the free end of a stethoscope or similar listening device along the seams in the leakage area. The leak can be detected by the change in sound when the instrument passes over it. After completing the test, remove the soapless bubble fluid from the outside of the aircraft by washing with clear water to prevent corrosion.

18-21. A few precautionary measures to follow during the testing procedure are:

a. With personnel inside, the area should never be pressurized to a pressure higher than has been previously established during testing with the section empty.

b. No person who has a cold or has recently had one, or whose sinuses are impaired in any way, should work in the pressurized section.

c. A qualified operator should be present at the pressurization equipment control panel at all times while the section is being pressurized. If the cockpit is being pressurized, all personnel should stand clear of the canopy.

18-22. Pressurization may not always be necessary to determine sealant defects. Sealants should be repaired or replaced when the following conditions are present:

a. Sealant is peeled away from the structure.

b. Seams are exposed through fillet seal.

c. Fillet or hole filling sealant is exposed through topcoating.

d. Sealant is damaged because of removal and installation of fasteners, access doors, or other sealed parts.

e. Crack or abrasions in sealant.

f. Air bubbles in sealant (air bubbles will expand at high altitude resulting in damage to seal).

g. Leakage occurs between sealed faying surfaces.

18-23. **Sealant Removal.** The tools used in sealant removal and fairing are locally manufactured. They should be of the sizes and shapes shown in figure 82. The materials used in their manufacture should be hardwoods with metal as an alternate and least recommended material. No tool should be made of a material harder than 2024–T3 aluminum alloy, and these must be used with care. Select the proper tool to be used according to the job that is to be done. Ingenuity will help you in the selection of the proper tool for the job at hand. The tools shown in figure 82 are those currently used in sealing maintenance work.

18-24. Repair defective fillet seals by removing the faulty sections from the fillet and applying new sealant. Remove fillets as follows:

a. Select the proper sealant cutting tools similar to those shown in figure 82.

b. Cut the faulty section from fillet.

c. Cut scarfs at ends of the section so that new sealant will lap remaining portions of old fillet in these areas. Avoid abrupt changes in cross section. Remove enough sealant on both sides of the defective area to be sure that the remaining material is satisfactory.

d. Examine all cut surfaces. Remove loose cuts or flaps. Make sure that no faulty sealant remains. If the old fillet adhesion is good, it is not necessary to cut the sealant to the bare metal.

18-25. Remove sealant around fasteners as follows:

a. Use a sharp cutting tool to cut around the seal and at the base of the fastener to separate the sealant from the structure. If the fastener is cap sealed, work the tool under the edge of the seal cover.

b. Grasp the seal or cover with a pair of pliers and pull it up away from the fastener end. Remove most of the seal by this process.

c. Carve away the remaining sealant with cutting tools.

18-26. **Sealant Application.** Several steps are to be followed in the application of sealants. The surface must be cleaned, and the sealant must be prepared and properly applied to insure a satisfactory seal.

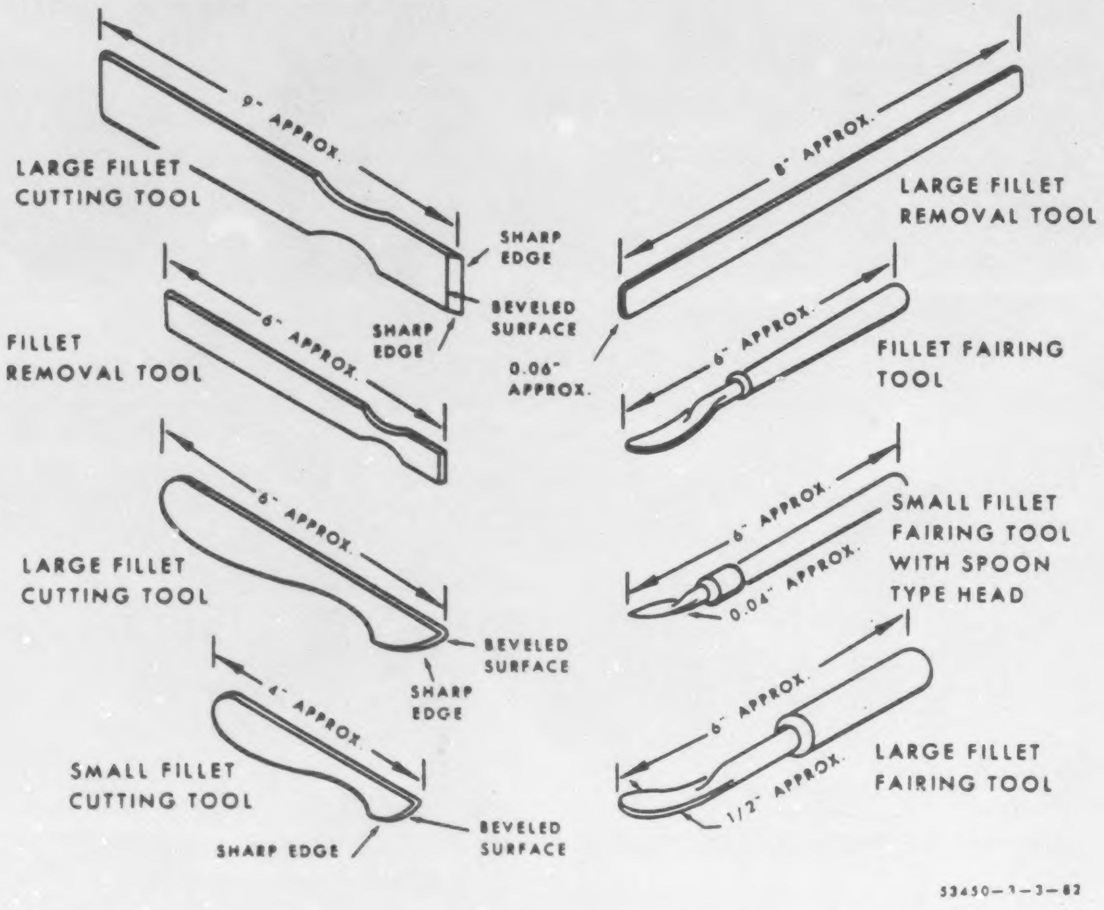

9" APPROX.
LARGE FILLET CUTTING TOOL
SHARP EDGE
BEVELED SURFACE
SHARP EDGE
6" APPROX.
FILLET REMOVAL TOOL
8" APPROX.
LARGE FILLET REMOVAL TOOL
0.06" APPROX.
6" APPROX.
FILLET FAIRING TOOL
6" APPROX.
LARGE FILLET CUTTING TOOL
BEVELED SURFACE
SHARP EDGE
6" APPROX.
0.04" APPROX.
SMALL FILLET FAIRING TOOL WITH SPOON TYPE HEAD
4" APPROX.
SMALL FILLET CUTTING TOOL
SHARP EDGE
BEVELED SURFACE
6" APPROX.
1/2" APPROX.
LARGE FILLET FAIRING TOOL
53450—1—3—82

Figure 82. Seal removal and fillet fairing tools.

18-27. *Cleaning the surface*. A surface that is to be sealed must be cleaned immediately prior to the application of the sealing compound. Sealant will not adhere to a surface which is not completely clean. Many types of impurities form a film over metal which is not visible but prevents proper adhesion of the sealant. For this reason, even those surfaces which appear to be clean must be cleaned as follows:

a. Preparation for adequate ventilation and/or the use of fresh air masks is mandatory. Cleaning solvents are toxic and flammable.

b. Clean a small area at a time. Clean an area twice as wide as that to be covered by the sealant.

c. Apply only a small amount of cleaner and wipe the surface dry with a clean, dry cheesecloth or equivalent until the area is soil free. Never use an excess amount of cleaner.

d. Do not touch the area with the fingers, because oil from the skin will leave a film on the metal and sealant will not adhere.

e. Repeat the cleaning process until there is no discoloration on the clean drying cloth.

18-28. *Preparation of sealing compound*. In preparing sealant, never compromise with the instructions. If the sealant does not go on smoothly, evenly, and easily, throw it away because further use will cause a poor sealing job.

18-29. A period of 6 months has been established as the age limit for unmixed packaged sealant. Sealant stored longer than 6 months is "outdated" and should be retested prior to using. A satisfactory check for out-dated sealant is to mix a container of base material with its accelerator and, at room temperature, determine the time required for a sample application to become tack-free. Compare this time with the corresponding maximum allowable tack-free time given in the applicable MIL specification. If this time exceeds the maximum allowable, discard the sealant. Store sealant at a temperature between 50° and 80° F. for best results.

18-30. Sealing compound handling is critical. Store, mix, and use sealant according to directions. Deviations from accepted procedures are not permitted since poor sealing can cause the loss of the aircraft and its personnel. Close surveillance of material worklife and cure time is absolutely necessary. The brushable type sealant must not be mixed before you are ready to use it because it has a worklife of only 2 hours at 21° C. (70° F.) When you use sealant, keep it covered if possible because the worklife decreases when the sealant is used from an open can. Addition of any thinner to one-part compounds after the sealant starts to thicken is not permissible. As the material thickens, it becomes harder to brush on and makes a smooth job impossible. When this occurs, discard remaining sealant. Sealing guns and nozzles must be cleaned in methyl ethyl ketone, Specification TT-N-261, before end of worklife of sealant.

18-31. One-part materials (high-temperature and firewall sealant) are compounded by the manufacturer and are ready for application as packaged. However, if thinning is desired, use thinner of same type as used by the manufacturer. When mixing two-part materials (all other sealants), mix the base compound with the matched accelerator in the proportions recommended by the compound manufacturer's instructions. Mix sealant by using the following procedures:

a. Weigh correct amounts of base compound and accelerator in clean, wax-free containers immediately prior to mixing. Control the scales and weighing procedure within 2 percent to insure good quality sealant.

b. Mix the components until the color is uniform. Do not whip air into the sealant.

c. Transfer the sealant into another clean container and complete mixing (an alternate method is to mix the sealant on a clean flat plate with a spatula).

d. Pour the sealant into a clean polyethylene gun tube or clean friction-top can. Label the tube or container with name and number of the sealant, date and time of mixing, and worklife expiration date and time.

18-32. *Application*. Always consult the applicable sections of the -3 technical order for the correct type of sealant to use in any application. Also given is the thickness and type of seal that is required for the various sections of the aircraft. The following information is general in nature and not to be used as an authority for application of sealants. Materials, type, and application procedures vary with different models of aircraft.

18-33. Different methods of application are used to properly seal different areas of the structures. In any type of application to any area of a structure, do not allow the recently sealed areas to become contaminated with foreign material. Also, do not allow the fresh, uncured sealant to be dislodged by jarring or vibration.

18-34. As previously mentioned, the following descriptions are general in nature and are not to be used as an authority. Always check and follow technical order instructions.

18-35. Fillet by applying a bead of sealant by hand or with a pressure gun at the parting line between two attached parts. Apply the sealant to the pressure side of the compartment. Press sealant into the parting line with a wooden or plastic tool. Use a brush to smooth it. If it is necessary to work near or on the repaired part before the sealant is cured, use a cloth-back tape to cover the sealant. This prevents damage and keeps foreign materials off the sealed area.

18-36. Injection sealing seals voids such as those that occur in corners and in areas adjacent to structures. The voids should be cleaned of all dirt, chips, burrs, grease, and oil before you do the injection sealing. Approximately a size number 32 drill should be used to drill a hole into the void. Never drill into the structure behind the void but only into the void. Drill holes one at a time or as necessary to permit the proper injection of the sealant. Apply the sealant to all confined holes, slots, and joggles until sealant is extruded at all openings to the confined area. For hard-to-reach areas, attach a length of plastic hose to the pressure gun tip.

18-37. Faying surface sealing is the application of sealant between mating surfaces of attached parts. To accomplish this, coat one surface with sealant before assembly of the parts. Apply enough sealant to form a bead of excess sealant along the joint after assembly. Assemble the parts while the sealant is freshly mixed.

18-38. Seal fasteners either during assembly or after assembly. To seal during assembly, apply sealant to the hole or dip the fastener in sealant. To seal after assembly, cover the pressure side of the fastener with sealant. When fasteners are installed through faying surfaces, the sealed parts need no additional sealing unless overcoating is required.

18-39. **Sealing Compound Curing.** Time required to cure sealant is dependent upon three factors: worklife of the sealant, ambient temperature, and relative humidity. High temperatures and high humidities shorten the cure; a long worklife sealant requires a longer curing period than a short worklife material. Cure may be accelerated by using heat, but sealant temperature should not exceed 49° C. (120° F.) Heat may be supplied by hot-air blowers, by heat lamps, or by prewarming the structure. Addition of water vapor to raise the relative humidity to approximately 60 percent (maximum advantage is reached at 60 percent relative humidity) will shorten the life of a two-part sealant. Heating alone is not always effective or practical. For example, if the aircraft is outside and ambient temperatures are near 10° C. (50° F.), any one of the following additives, when added to certain sealant materials, will accelerate cure when ambient temperatures are between 10° or 21° C. (50° or 70° F):

a. Isopropyl alcohol, Specification MIL–F–5566, may be added during mixing in proportions not to exceed 3 percent by weight of the base compound. This particular mixture will craze acrylics.

b. Distilled or deionized water may be added during mixing in proportions not to exceed 3 percent by weight of the base compound.

c. Aqueous solution of sodium bicarbonate, Specification O–S–576, saturated at 25° (±2°) C. (77° ± 5° F.) in proportion not to exceed 3 percent by weight of the base compound.

d. When ambient temperatures are above 21° centigrade (70° F.) and relative humidity is above 60 percent, it is not necessary to use additives to accelerate curing time.

18-40. **Aerodynamic Smoothers.** Modern aircraft external structures must be aerodynamically smooth. Damage or repairs that change the shape or roughen these surfaces (especially in critical areas) reduce the performance of the aircraft. Aerodynamically smooth aircraft reach the top speeds and range requirements for which they were designed. Aerodynamic smoothness affects takeoff and landing speeds; it controls the effectiveness of the aircraft at various flying speeds. You can see that you must maintain the original aerodynamic contour and smoothness when you repair or modify external structures.

18-41. *Types of smoothing compounds.* There is a specific type of smoothing compound or filler for each aircraft. Applicable technical manuals or orders lists the specific compound for that particular aircraft and procedures to be used in its application. You will find that smoothing compounds are manufactured in the form of pastes and putties and are of two basic types. One-part compounds use chemical action to control the speed of curing. Two-part compounds are composed of a filler and an accelerator to control the setup or curing time. Before you select any smoothing compound or filler, always consult the technical order for specified requirements for the particular aircraft.

18-42. *Preparation.* You should take certain steps when preparing to apply a smoothing compound or filler. The following steps are general in nature and may be used as a guide. Applicable technical orders will furnish you with specified procedures and cleaning agents.

a. Remove all primers or organic paint finishes for the distance along each side of the area as recommended by the technical order.

b. Use aliphatic naphtha, brightener, or specified cleaner to clean the area to be filled. Apply cleaners with a clean cheesecloth or brush.

c. After application of the cleaner, rinse the area clean with water and wipe the area. Allow the surface to dry thoroughly.

d. Repeat the cleaning process as necessary until the area is completely free of any residual film or foreign matter.

18-43. *Mixing smoothing compounds.* The two-part smoothing compounds require mixing of the base compound (filler) with an accelerator. When working with a two-part compound, be sure that the number on the filler can (batch number) is the same number as that on the accelerator can (curing agent). The base compound must be measured and mixed by weight or volume in proportions recommended by the manufacturer. The directions for mixing are on the can and should be followed closely.

18-44. Mix these compounds at room temperatures. It is recommended that they be used within a specified time after the accelerator has been added to the base compound. Accelerated smoothing compounds or fillers may be stored for a limited time at controlled (refrigerated 0° to 10° F.) temperatures.

18-45. Thorough mixing of smoothing compounds or fillers is necessary. Poorly mixed compounds lack the proper consistency and fail to cure properly, have improper setup or hardness, and/or have air bubbles that leave pits or holes in the finished surface.

18-46. Toxic fumes are given off during the blending process. To minimize these fumes, adequately ventilate the area. A few rules to follow when mixing compound are:

a. Do not inhale the vapors.
b. Add the accelerator slowly.
c. Mix the two parts in recommended portions.
d. Be careful and keep the accelerator off hands and clothing.
e. Consult technical orders for bench life of the compound.

18-47. *Application of compounds.* After the surface has been properly cleaned and thoroughly dried, apply the smoothing compound or filler with a putty knife or spatula. Work the compound over the area evenly and force enough into slots, crevices, or heads of recessed screws to allow a slight excess (overfill) for shrinking during curing time. Avoid air bubbles during application of the compound. They will cause pits or holes in the finished surface.

18-48. *Curing and finishing.* The smoothing compound or filler must be allowed to dry (cure) thoroughly according to the time given by technical orders for prevailing conditions. Always consult the technical orders for specified curing times for the compound being used in relation to temperature and humidity at time of application.

18-49. After the area has completely dried, remove the excess compound by either machining, filing, and/or sanding, depending on the hardness of the surface. In either case, the final step is the feathering of the edges and wet sanding the surface for a smooth contour. Use a wooden block padded with the recommended (320 to 400) grit wet sandpaper dipped frequently in water. During the removal of excess compound, be careful to avoid marring the surfaces and causing unnecessary repairs to the finished areas.

18-50. After sanding, clean the area with a recommended cleaner and allow to dry thoroughly. If applicable, prime the area with zinc chromate and coat it with aluminized lacquers or other coatings, as recommended by technical orders.

18-51. **Metal Fuel Tank Repair.** Usually, a fuel system repairman inspects, seals, and performs as much of the repair as he can. When he finds metal damage beyond his capability to repair, he will need your help. You may have to install replacement rivets in stringers, ribs, bulkheads, webs, etc., of the tanks to make them serviceable. If the damage is severe enough to require replacement of a portion of the wall of the tank, remove the damaged area, select the correct metal for the replacement patch, and prepare and install the patch. Most exterior tanks require a flush, butt-welded, splice type patch; most interior tanks require an overlapping patch.

18-52. *Rivet replacement.* When you replace rivets on a tank, consider these factors. If the task requires you to work inside the tank, observe all safety precautions. Protective cotton clothing, respirator, supply of fresh air, safety guard, explosive-proof flight, and air-driven tools are necessary if you are to be safe when riveting inside a tank. Check the inside of the tank with an explosimeter to determine the fuel vapor concentration of the air inside the tank. Never enter the tank until a safe reading is obtained. Use the knowledges you acquired earlier to remove, select, and install rivets. Never use explosive rivets or electrically powered tools when making these repairs.

18-53. *Patching.* Metal fuel tanks may be so severely damaged that they require replacement of a section of the wall. When you determine that partial replacement is the best method of repair, remove the damaged area and prepare a flush butt-splice-type patch of the same thickness and type of material. Then metal processing personnel will weld the patch in place.

18-54. In other instances, you may be required to prepare a patch plate to cover the area. If you are, remove all damaged material and prepare a patch plate for the area. Select the correct metal composition and thickness, type of rivet, edge distance, and tools necessary for installation. Information given earlier in this course will help you to perform this type of repair.

Control Surface Balancing

DO YOU REMEMBER what happened when you lost your balance while you were learning to ride a bicycle? It was necessary to have equal pressure on the handlebars to keep your balance. If you have watched a balancing act on TV or at the circus, you are aware of the importance of balance and the skill of the performer in shifting the bar to maintain a horizontal position. If an aircraft control surface is not correctly balanced, the result could be just as devastating.

2. Any time repairs on a control surface add or subtract weight fore or aft of the hinge centerline, the control surface must be rebalanced. Any control surface that is out of balance will not be stable and will not remain in a streamlined position during normal flight and will cause the surface to flutter or buffet. For example, consider an aileron that is trailing edge heavy. It moves down when the wing deflects upward and moves up when the wing deflects downward. Such a condition can cause unexpected and violent maneuvers of the aircraft. In extreme cases, fluttering and buffeting may develop to a degree that could cause the loss of the aircraft.

3. In this chapter you will review the terms and principles you use in balancing control surfaces. You will study moment-of-force computation and the four methods of balancing a control surface. Finally, you will study metals used as weight for surface balancing. After you have studied this chapter, you should be able to compute weights required to balance control surfaces, explain why a particular metal was selected for the weight, and explain why one method of balancing control surfaces would be selected over another.

4. Do not use the material in this chapter to balance control surfaces. Detailed instructions for balancing these surfaces are contained in the -3 technical order for the specific aircraft and must be followed.

19. Balancing Principles

19-1. When rebalancing a control surface, you are concerned with both static and dynamic balance. If you statically balance a control surface correctly, it will also be correctly balanced dynamically.

19-2. **Static Balance.** Static balance is the tendency of an object subjected to forces of gravity only to remain stationary about an axis of rotation at its own center of gravity. The two ways in which a control surface may be out of static balance are underbalance and overbalance.

19-3. When a control surface is mounted on a balance stand, a downward travel of the trailing edge below the horizontal position indicates underbalance. Some manufacturers specify this condition with a plus (+) sign. Example A of figure 83 illustrates the underbalance condition of a control surface.

19-4. An upward movement of the trailing edge, above the horizontal position, indicates overbalance. Example B of figure 83 illustrates the overbalance condition of a control surface. Some manufacturers specify this condition with a minus (−) sign. These signs (+ or −) indicate the need for more or less weight in the correct area to balance the control surface. Example C of figure 83 illustrates the balanced condition of a control surface.

19-5. A tail-heavy condition (static underbalance) causes undesirable flight performance and is usually not allowed. Better flight operations are gained by nose heaviness (static overbalance). Most aircraft manufacturers advocate the existence of nose heavy control surfaces.

19-6. **Dynamic Balance.** Dynamic balance is that condition wherein all forces acting on a body in motion are balanced equal so that the body does not vibrate while in motion. Dynamic balancing, as related to control surfaces, is the effort to maintain balance when the control surfaces move forward (as on the aircraft in flight). Dynamic balancing involves attaching weights in the correct places along the span of the surfaces. In most cases, the weights are added forward of the hinge centerline.

19-7. **Balancing Terms.** Terms and symbols with meanings useful in understanding the procedures for balancing, solving formulas, and locating reference points are as follows:

Weight Reaction (W_R). Weight reaction is the gross or calculated net weight used in the calculation of formulas to bring about a balanced condition in a control surface unit or an individual component. It is expressed and recorded to the nearest hundredth of a pound and is obtained with the chord line in a horizontal position. This position is illustrated in figure 84.

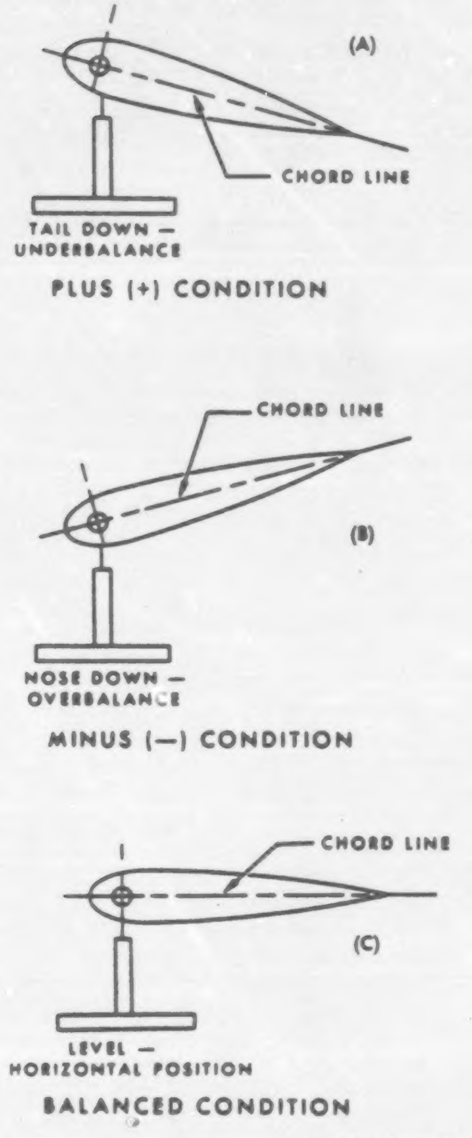

(A)
CHORD LINE
TAIL DOWN — UNDERBALANCE
PLUS (+) CONDITION
CHORD LINE
(B)
NOSE DOWN — OVERBALANCE
MINUS (—) CONDITION
CHORD LINE
(C)
LEVEL — HORIZONTAL POSITION
BALANCED CONDITION
53450—3—4—83

Figure 83. Control surface static balance.

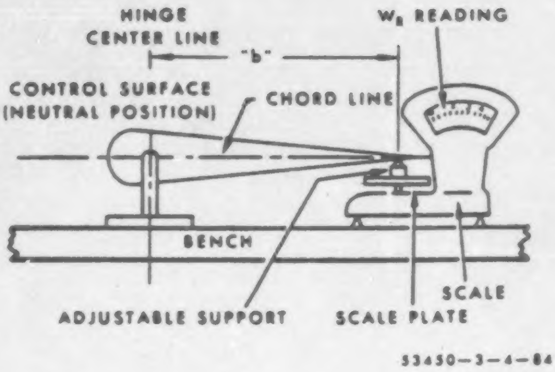

HINGE CENTER LINE
"b"
W_R READING
CONTROL SURFACE (NEUTRAL POSITION)
CHORD LINE
BENCH
SCALE
ADJUSTABLE SUPPORT
SCALE PLATE
53450—3—4—84

Figure 84. Weighing overbalance or underbalance.

Weight reaction is also defined as the force (in pounds) that is exerted upon the control surface causing it to move clockwise or counterclockwise. In figure 84, weight reaction is the pounds reading of the scale as the trailing edge of the control surface pushes down on the adjustable support and scale plate.

Control Surface Assembly Weight (W_S). Weight (W_S) is the *total* weight of a control surface assembly. For example, to determine the weight (W_R) of an inboard aileron, include the weight of the tab assembly, tab control push rod, nose seal, hinge fabric seal, and the hinge fabric seal retaining nut as well as the weight of the inboard aileron assembly. In other words W_S is the total weight.

Weight (W). In some aircraft, weight (W) is considered to be the weight of an individual *part* of a control surface unit. Examples of such parts would be tabs, balance panel, aileron, etc.

Panel Weight (W_P). This is the actual weight of a complete balance panel including the aft hinge pin and retainer and the forward fabric seal.

Center Of Gravity (cg). In rebalancing control surfaces the center of gravity is that point at which the surface can be balanced in any position. It is also the point of load concentration.

Hinge Centerline (HC_L). The hinge centerline is the axis about which the control surface rotates. This line is illustrated in figure 84.

Minus Or Negative Sign (−). This sign was mentioned earlier. In rebalancing control surfaces, the minus sign is sometimes used to indicate an overbalance condition. A minus or negative sign preceding weight reaction (W_R) value means that the leading edge tends to move in a downward direction with the control surface in an overbalanced condition. This condition is normal on some aircraft and should exist on the control surfaces of these aircraft. The applicable technical orders list the acceptable limits for this overbalance condition.

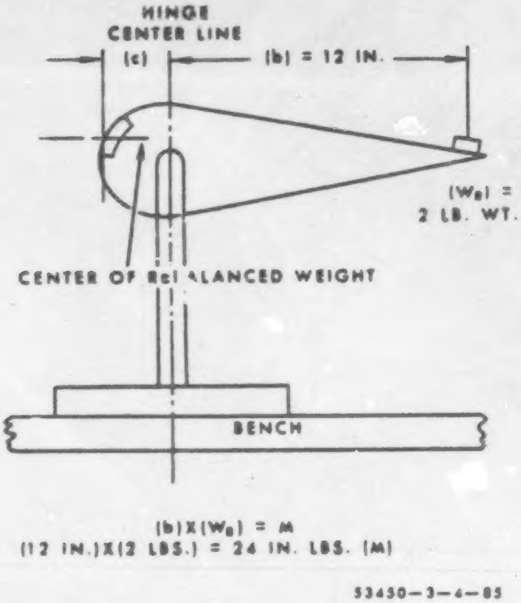

HINGE CENTER LINE
(c)
(b) = 12 IN.
(W_R) = 2 LB. WT.
CENTER OF REBALANCED WEIGHT
BENCH
(b)X(W_R) = M
(12 IN.)X(2 LBS.) = 24 IN. LBS. (M)
53450-3-4-85

Figure 85. Effect of weight and distance.

PLUS OR POSITIVE SIGN (+). This sign was also mentioned earlier. It is sometimes used to indicate an underbalance condition. A plus or positive sign preceeding weight reaction (W_R) value indicates that the trailing edge tends to move downward. This downward movement means that the control surface is in an underbalanced condition, and the unit must be rebalanced to the limits specified in the applicable technical order.

SYMBOL b. The symbol, or letter, b represents the measured distance from the hinge centerline (HC_L) to weight reaction (W_R) at the point of the adjustable support or weight. This distance is referred to as the moment arm b. The distance is measured, expressed, and its value recorded to the nearest hundredth of an inch. Moment arm b is illustrated in figures 84 and 85.

SYMBOL C. The symbol, or letter, C represents the measured distance from the hinge center line to the center of the rebalance weight location. This distance is also measured and expressed and its value recorded to the nearest hundredth of an inch. Distance C is illustrated in figure 85, and is usually forward of the hinge centerline.

MOMENT (M). Moment is the term applied to the combination of force (weight) and distance. Moment (M) is defined as "the tendency of a force to cause rotation about a given axis." A simple example is that of a force being applied with a wrench to turn or tighten a nut. Moment is illustrated in figure 85 at $M = b \times W_R$. An example of the formula and the solution is given at the bottom of figure 85.

19-8. **Moment of Force Computation.** The principles that are essential in the balancing or rebalancing of the control surfaces are easy to understand if a simple comparison is used. For example, a child's seesaw that is out of balance may be compared to a control surface that does not have balance weights installed. The comparison is illustrated in figure 86. Look carefully at the top half of the figure. From this part of the figure it is easy to see how a control surface is naturally tail (trailing edge) heavy.

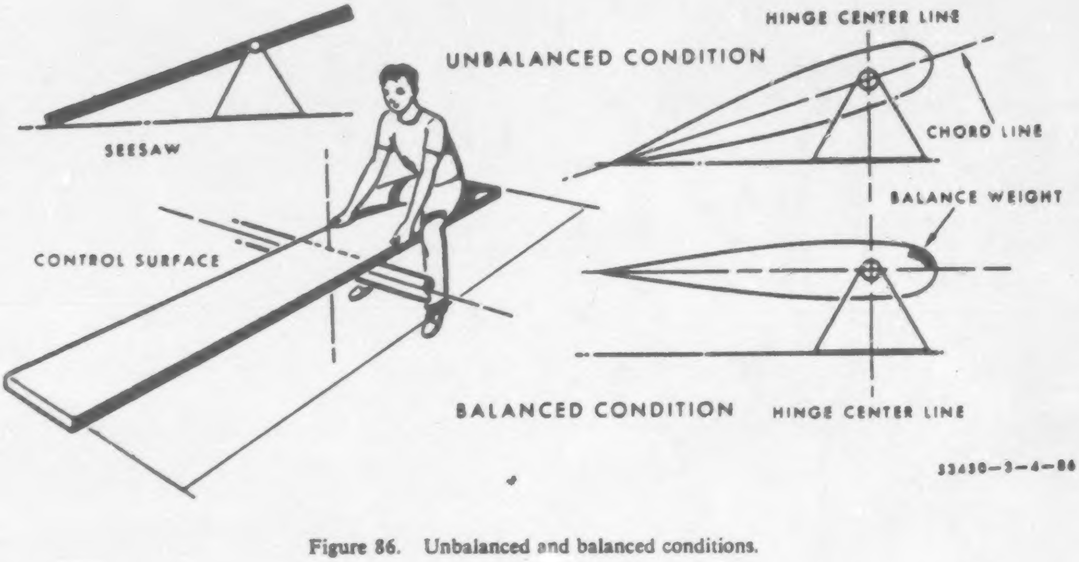

HINGE CENTER LINE
UNBALANCED CONDITION
CHORD LINE
SEESAW
BALANCE WEIGHT
CONTROL SURFACE
BALANCED CONDITION
HINGE CENTER LINE
53450-3-4-86

Figure 86. Unbalanced and balanced conditions.

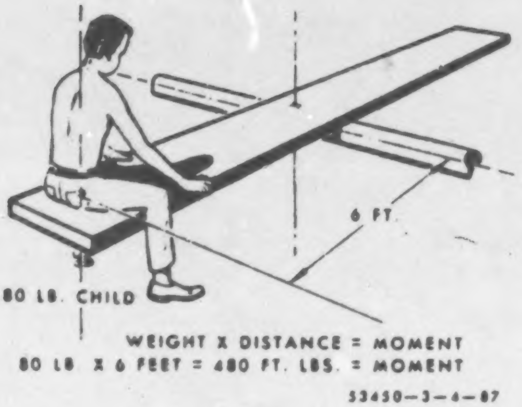

6 FT.
80 LB. CHILD
WEIGHT X DISTANCE = MOMENT
80 LB. X 6 FEET = 480 FT. LBS. = MOMENT
53450—3—4—87

Figure 87. Moment.

19-9. As stated earlier, it is this out-of-balance condition that causes a damaging flutter or buffeting of the aircraft and must be eliminated. The out-of-balance condition is corrected by adding weights either inside or on the leading edge of the tabs, to the horns on the inboard ailerons, or in the proper location on the balance panels. When the correct size weights are added at the correct places, the balanced condition exists and can be compared to the seesaw with a child siting on the short end of the plank, as illustrated in the bottom portion of figure 86.

19-10. The effects of moments on control surfaces is easily understood by a closer observation and study of a seesaw and two children of different weights seated in different positions on the seesaw. Figure 87 illustrates a seesaw with an 80-pound child seated 6 feet from the fulcrum. The weight of the child rotates the seesaw clockwise until the plank touches the ground. To bring the seesaw back to the level position (or balanced condition), we place another child on the opposite end of the seesaw. The child we place on the opposite end of the seesaw must be placed at a certain distance from the fulcrum and be of an exact weight in order to equalize the moment of the child on the left side of the seesaw.

19-11. Refer to figure 87 again. Suppose we place the child (that we added on the opposite end of the seesaw) 8 feet to the right of the fulcrum. A simple formula is used to determine the exact weight this child must have to balance the child on the left of the fulcrum and bring the seesaw back to the level condition.

19-12. To produce a balanced condition of the seesaw (or control surface), the clockwise moment must equal the counterclockwise moment. Moment is found by multiplying weight times distance. Therefore, the formula to balance the seesaw is:

$$W_2 \times D_2 = W_1 \times D_1$$

W_2 is the unknown weight of the second child. D_2 is the distance in feet the second child is seated from the fulcrum (8 feet). W_1 is the weight of the first child (80 pounds). D_1 is the distance in feet the first child is seated from the fulcrum (6 feet).

19-13. Finding the weight of the second child is now a matter of substituting and solving the formula as follows:

$$\begin{aligned} W_2 \times D_2 &= W_1 \times D_1 \\ W_2 \times 8 &= 80 \text{ pounds} \times 6 \\ W_2 &= \frac{480 \text{ pounds}}{8} \\ W_2 &= 60 \text{ pounds} \end{aligned}$$

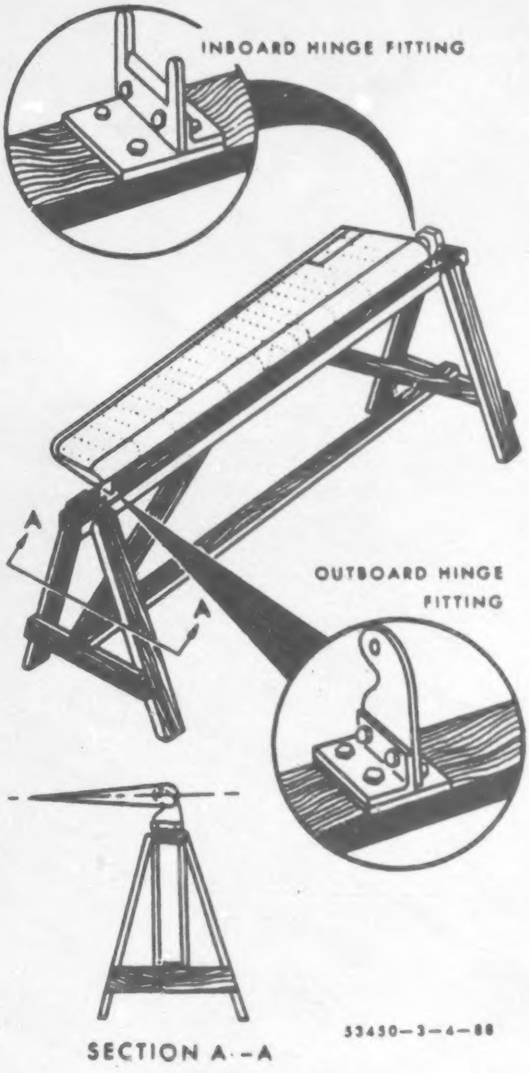


Figure 88. Field type balancing jig.

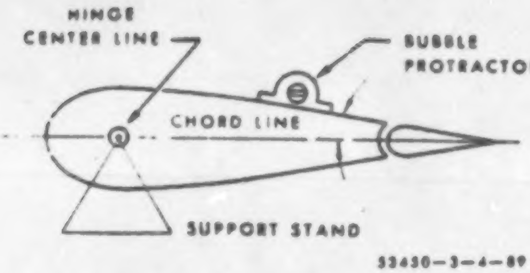


Figure 89. Establishing a neutral position.

19-14. The weight of the second child must be 60 pounds. To prove the formula:

60 pounds × 8 feet = 80 pounds × 6 feet
480 foot pounds = 480 foot pounds

19-15. The seesaw is now in a balanced condition, since the clockwise moment around the fulcrum equals the counterclockwise moment.

19-16. The same effect is obtained in a control surface by adding weights forward of the hinge centerline. Most of the repairs to control surfaces are aft of the hinge centerline and result in a trailing edge heavy condition. The correct rebalance weight must be calculated and installed in the proper place.

20. Balancing Procedures

20-1. We have pointed out that repairs to a control surface or its tabs generally increase the weight aft of the hinge centerline and require static rebalancing of the control surface system as well as tabs. When you determine that a control surface needs to be rebalanced, remove the surface from the aircraft and support the surface from its own points on a suitable stand, jig, or fixture. Figure 88 is an illustration of a field type balancing jig.

20-2. When the control surface is mounted on the stand, secure the trim tabs on the surface in the neutral position. Be sure the stand is level and located in an area free of air currents. The control surface must be free to rotate about the hinge points. Overbalance or underbalance condition is determined by the direction the trailing edge moves when the surface is suspended from its hinge points. Any excessive friction causes a false reaction as to the overbalance or underbalance of the surface.

20-3. When you install the control surface in the stand or jig, establish the neutral position of the surface with the chord line of the surface in the horizontal position, as illustrated in figure 89. Use a bubble protractor (set at the correct angle specified in the applicable technical order) to determine the neutral position before continuing the balancing procedures. Sometimes, a visual check is all that is needed to determine whether the surface is balanced or unbalanced.

20-4. **Methods.** Four methods of balancing (rebalancing) control surfaces are used by the various manufacturers of aircraft. The four methods are commonly called calculation method, scale method, trial weight (trial and error) method, and component method.

20-5. *Calculation method.* The calculation method of balancing a control surface is directly related to the principles of balancing discussed earlier. It has one advantage over the other methods: it can be accomplished without removing the surface from the aircraft.

20-6. When you use the calculation method, you need to know the weight of the material removed from the repair area and the weight of the materials used to fabricate the repair. Subtract the weight removed from the weight added to get the net gain in weight added to the surface.

20-7. Measure in inches the distance from the hinge centerline to the center of the repair area.

NOTE: This distance must be measured parallel to the chord line of the surface as illustrated in figure 90. This distance must be measured to the nearest hundredth of an inch.

20-8. Next multiply this distance by the net weight of the repair. The answer will be in inch-pounds. Consult the -3 technical order for the specific aircraft to determine any further actions. If the inch-pounds result of the calculations is within specified tolerances, consider the control surface balanced. If the result of the calculations is not within specified limits, the technical order will specify the needed weights, the material to use to fabricate the weights, the design for manufacturing the weights, and the installation locations for addition of the weights.

20-9. *Scale method.* The scale method of balancing a control surface requires the use of a scale that is graduated in hundredths of a pound. A support stand and balancing jigs for the surface are also required. Figure 91 illustrates a control sur-

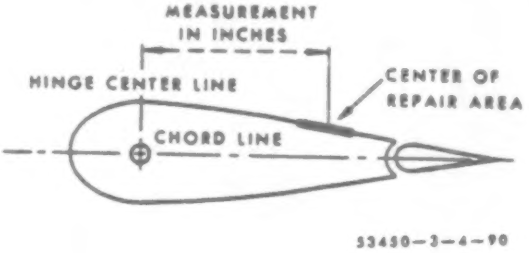


Figure 90. Calculation method measurements.

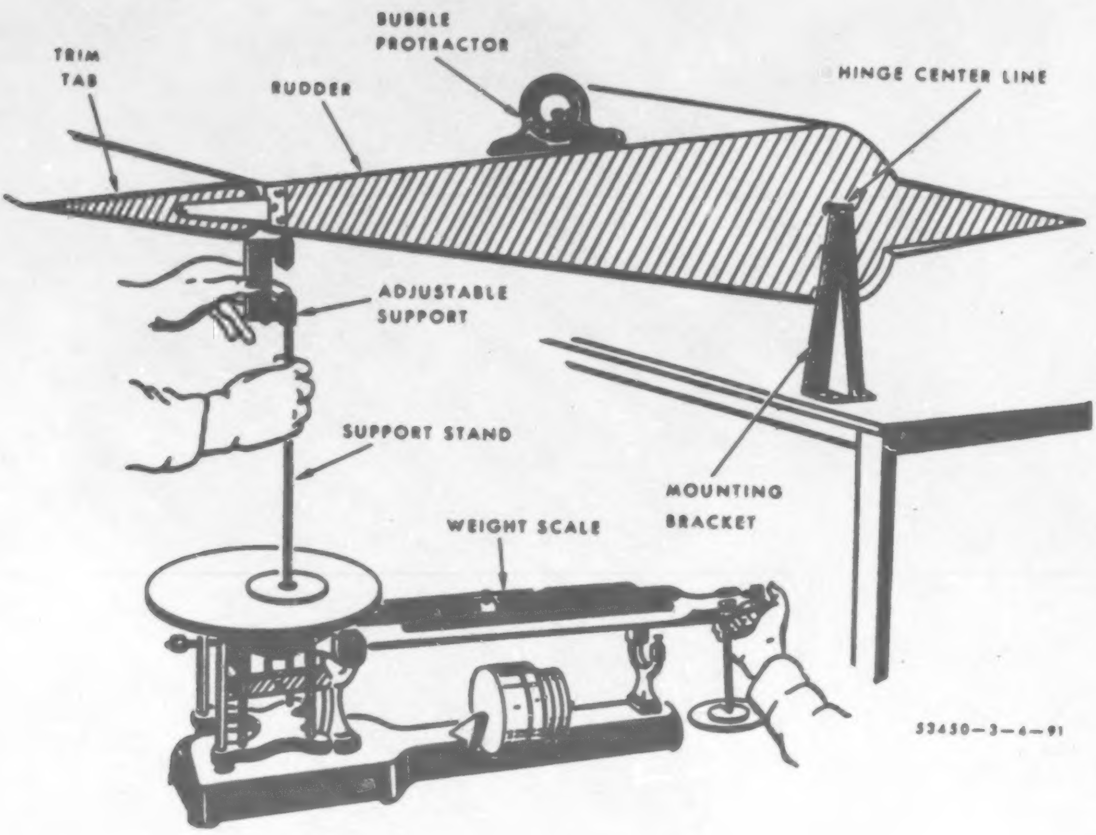


Figure 91. Balancing setup.

face mounted for rebalancing purposes by the scale method.

20-10. Use of the scale method requires the removal of the control surface from the aircraft. *Technical orders must be consulted to determine removal procedures and parts or assemblies to be left attached to the surface.*

20-11. Before you rebalance the control surface, place it in the neutral or level position. Use the bubble protractor set at the correct angle (as specified by the applicable technical order for the particular aircraft) to make sure the chord line is in the horizontal position.

20-12. Since the adjustable support is located on the scale, you must account for this weight when you obtain the weight reactions. Account for this weight by either (1) weighing the adjustable support fixture separately and subtracting this weight from the total weight reaction or (2) setting the scales to zero after the adjustable support fixture has been mounted.

20-13. Since most repairs to control surfaces are performed aft of the hinge centerline, the trailing edge will usually push down on the support stand and scale.

NOTE: Consult the -3 technical order for the specific location of the support stand when you balance a control surface by the scale method.

20-14. The reading on the scale (to the nearest 1/100 inch) will be either a gross or a net weight reaction. You need to know the net weight reaction to use the table in the technical orders.

20-15. To counteract the net W_R add an equal amount of weight to the forward section of the control surface. *Consult the applicable tables of the -3 technical order for size, material, and location of weights needed to counteract the W_R.*

20-16. *Trial weight method.* The trial weight method is a way of balancing a surface by using a known weight. The weight is positioned chordwise on the surface to bring the chord line level.

20-17. The trial weight method consists of using a weight of known value in the rebalancing procedures. Steps to be followed in the use of this method are:

a. Place the control surface in a job or support stand. Check for friction free rotation about the hinge point.

b. Consult the technical order for the specific aircraft and control surface to determine the value of the weight to use.

c. From the applicable technical order table, determine the limits (along the chord line of the surface) between which the selected weight would have to be placed to balance the surface.

d. Obtain the selected weight. By locating it within the limits, determine whether the weight will balance the control surface.

e. If the above steps result in a balanced control surface, no further action is necessary.

f. If the control surface is not in a balanced condition as the result of the above procedures, additional weight must be added on the opposite side of the hinge centerline. Do this by selecting material and placing it in any available location. When enough of the selected material has been used to balance the surface, mark the location of the material and weigh the material. A weight should be locally manufactured (or obtained from supply, if available) and placed in the location previously marked. Installation can be accomplished by using whatever fastening devices are available.

20-18. *Component method.* The component method of rebalancing is actually a combination of the scale and calculation methods. It consists of balancing each component by itself. Each component would maintain a specified amount (W_H) about the hinge centerline of the surface. Control surface installations made up of these components must be balanced within limits specified by technical orders. All components balanced by this method are considered to be interchangeable with other components on alternate complete units.

20-19. **Balance Weights.** After the required rebalance weights have been calculated, they must be fabricated and installed properly. The rebalance weights may be made from fan steel, lead, arch bronze, corrosion resistant steel, or 4130 steel.

20-20. The weight of these metals are useful in the fabrication of the rebalance weights and are as follows:

Lead	0.41-pound per cubic inch
Fan steel	0.602-pound per cubic inch
4130 steel	0.28-pound per cubic inch
Corrosion resistant steel	0.31-pound per cubic inch

20-21. The –3 technical order for the specific aircraft usually gives the exact dimensions and material to use for local manufacture of weights needed to balance control surfaces. In many cases, the location and the amount of clearance needed determines the size and material of the weight.

*U. S. GOVERNMENT PRINTING OFFICE: 1974-640-058/268

2-3 374

53450 03 26

WORKBOOK

Aircraft Structural Repairs

SELF-TEACHING AIDS
CRE
VRE
SRG

This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Study Reference Guide, the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, "Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

EXTENSION COURSE INSTITUTE
Air University

TABLE OF CONTENTS

Study Reference Guide

Chapter Review Exercises

Answers For Chapter Review Exercises

Volume Review Exercise

ECI Form No. 17

MODIFICATIONS

Pages 2- 4 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER REVIEW EXERCISES

CHAPTER 2

Section 6

Objective: To be able to select and identify the correct rivet for the job at hand.

1. Describe the difference between the heads on the opposite ends of a rivet. (6-2)

2. Why is the 2117T rivet in wide demand? (6-8)

3. Explain the difference in the use of 1100, 2017T, 2117T, and 5056 rivets. (6–7–9)

4. Explain the purpose of storing 2024T rivets in an electric refrigerator. (6-15)

5. What is the result of riveting two sheets of 2024T with monel rivets? (6-22)

6. Why is a countersunk-head rivet preferred to a universal-head rivet on the exterior of an aircraft? (6-27)

7. Describe the significance of the markings on the heads of rivets. (6-28, 29)

8. Describe a rivet that has the part number MS20470DD–5–70. (6-30 –32)

Section 7

Objective: To be able to use and care for the pneumatic riveter.

1. Explain the differences between riveting with the hand squeeze riveter and the pneumatic squeeze riveter. (7-5)

2. How do you lubricate the internal parts of the pneumatic riveter? (7-8)

Section 8

Objective: To be able to prepare the hole, install and drive the rivet, and inspect the completed work.

1. You are to fasten a piece of 0.032 sheet stock to a piece of 0.064 sheet stock. What is the minimum dameter of the rivet you use to fasten this stock? (8-6)

2. Explain the difference between rivet pitch and transverse pitch. (8-14)

3. Describe the way to space rivets in a single-row, two-row, and three-row layout. (8-16)

4. Which bucking bar do you select to speed up the process of riveting the skin on wing sections?

5. What is the purpose of a dimple around a rivet hole? (8-29)

6. Under what conditions would you sometimes select a twist drill with an included angle of 90° in preference to one having an included angle of 118°? (8-36)

7. What are the common causes of elongated countersunk wells? (8-47)

8. What are the advantages of coin dimpling? (8-58)

9. What device is used on all thermo dimpling equipment to insure fully automatice cycling, heating, and timing control at all times? (8-68)

10. Describe the required condition of the hole and the parts to be riveted before you drive the rivet. (8-74)

11. When hand-driving rivets, why do you keep the hammer strokes to a minimum? (8-81)

12. When using a pneumatic rivet gun, how should you hold the rivet set in relation to the part being riveted? (8-84)

13. Portable squeezers are particularlyly suited for what type of assemblies? (8-87)

14. How can you identify rivets that have been properly microshaved? (8-90)

15. Describe the types of rivet failures. (8-92–94)

16. When you drill a rivet to remove it, how can you tell when you have driven through the head of the rivet? (8-103)

Section 9

Objective: To be able to select and install the correct Hi-Shear rivet.

1. What are the advantages of a Hi-Shear pin rivet over the bolt, washer, and nut combination? (9-1)

2. Describe the difference between driving a Hi-Shear pin rivet from the collar end and the head end. (9-8, 9)

Section 10

Objective: To be able to select and identify the correct mechanical expansion rivet and to describe installation processes and inspection items.

1. What are the two parts of a self-plugging (friction lock) rivet? (10-4)

2. Describe the sequence of events when a pulling force is applied to the stem of a self-plugging (friction lock) rivet. (10-5)

3. Explain why self-plugging (friction lock) rivets can be used to attach assemblies to plywood or plastics. (10-9)

4. The tools used to install self-plugging (friction lock) rivets are mde by ______________. (10-15)

5. After installing a self-plugging (friction lock) rivet, how do you trim the stem to achieve aerodynamic smoothness? (10-21)

6. What inspection is made on the head of an installed self-plugging rivet? (10-23)

7. Describe the sequence of events when a pulling force is applied to the stem of a self-plugging (mechanical lock) rivet? (10-28)

8. What unit of measurement is used for the grip range on both the Cherry-Lock rivets and Conical Keystone Lock rivets? (10-34)

9. What are the procedures for installing self-plugging rivets (10-40)

10. Why is a pull-thru rivet structurally weak? (10-43)

11. When would you select a closed-end Rivnut in preference to an open-end Rivnut? (104-8)

12. What coding is used on Rivnuts to indicate the minimum grip lenght? (10-49)

13. Under what conditions would you use a small, round file to cut a keyway in preference to the keyway cutter? (10-54)

14. When would you select a key type Rivnut in preference to one without a key? (10-58)

15. How should the shank of an installed Rivnut fit in the hole? (10-59)

16. Is machine countersinking preferable to dimpling when Rivnuts are used to join sheets together? (10-62)

17. Why does the completed installation of the Rivnut require a plug or a screw? (10-65)

18. Why are the aluminum parts of the Lok-Rivet and the Lok-Skru anodized? (10-70)

19. How should a Lock-Skru tool be inserted? (10-73)

20. What is the shear strength of a Deutsch rivet? (10-76)

21. Explain the result of shaving or milling the heads of Deutsch rivets. (10-81)

Section 11

Objective: To be able to select and identify the correct lockbolt and explain reasons for this selection.

1. Name the types of lockbolts. (11-2)

382

2. Under what conditions do you select a stump type lockbolt in preference to a pull type lockbolt? (11-4)

3. How is the Lock-Bolt grip length determined? (11-10)

4. What inspection is required on the lockbolt collar? (11-13)

Section 12

Objective: To be able to select and identify the correct style turnlock for installation.

1. The head of a style I turnlock fastener is marked F 6½ .50. Describe the fastener. (12-5)

2. Which of the three turnlock fasteners has a stud assembly that is never disassembled? (12-12–13)

3. Which of the three turnlock fasteners has a cross-pin that is not reusable? (12-21)

CHAPTER 3

Section 13

Objectives: To be able to select and identify the correct common fastener and explain why the selection was made, and to explain use and operator maintenance of spot welds for airframe repair.

1. Where are bolts used on aircraft? (13-1)

2. When you install bolts or screws, what item is needed to make the bolt installation complete that is not necessarily needed with screws? (13-4)

3. How does the grip length of a bolt compare with the grip length of a screw the same size? (13-5)

393

4. **Aircraft bolts are made from what material? (13-8)**

5. **When you use internal wrenching bolts in dural material, why is a special heat-treated washer required? (13-13)**

6. **Describe how the blind head of a Jo-Bolt is formed during the driving process. (13-27)**

7. **Explain the difference between aircraft self-locking and non-self-locking nuts. (13-37)**

8. **What general type of nut would you be using if you are required to safety the nut? (13-38, 39)**

9. **What type of nut would you find in a section of the aircraft subject to constant vibration? (13-45)**

10. **Why is the slot in the insert of the stainless steel self-locking nut wider than the key on the case? (13-50)**

11. **Explain the principle of the eleastic stop nut. (13-53)**

12. **Describe the difference between a tigh-drive fit and a light-drive fit of bolts and bolts holes. (13-60)**

13. **What is the reason for drilling bolt holes to an exact size? (13-63)**

14. **When installing bolts and nuts, what tool should you use to finish tightening the nut? Why? (13-64)**

15. **What are three kinds of aircraft washers? (13-67)**

16. **List two uses of the AN960 and AN970 washers. (13-68)**

17. Which washer do you use to help obtain the correct grip length for a nut and bolt assembly? (13-68)

18. You are required to install steel lock washers on aluminum alloy skin. What is also required for this type of installation? (13-72)

19. Which of the aircraft screws is the general purpose screw? (13-82)

20. What would be the part or code number for an AN fillister-head, fine-thread, corrosion-resistant steel screw, ¼ inch in diameter and ½ inch in length? (13-86; Fig.57)

21. What is the prime objective of all welding? (13-91)

22. What is the main difference between seam welding and spot welding? (13-92, 96)

23. Where are portable gun spot welders used? (13-95)

CHAPTER 4

Section 14

Objectives: To be able to identify the various types of aircraft construction, explain the purpose of each, and describe the advantages of one type structure over another; and to identify the flight control axes and to explain how flight is controlled around each axis.

1. Identify and explain the big weakness of the true monocoque type construction. (14-5)

2. What is the purpose of stringers? (14-9)

3. Explain the difference between monospar, multispar, and box beam types of wing constuction. (14-18–21)

4. Describe the I-bean type of constuction for a spar. (14-26)

5. What is the purpose of fairing? (14-34)

6. Name the flight axis and the major control surface that controls each. (14-40, 41; Fig. 63)

7. Expalin the difference between ground-adjustable and flight-adjustable trim tabs. (14-46, 47)

8.. Explain the purpose of elevons and flaperons. (14-54)

Section 15

Objective: To be able to explain aerofynamic forces and rpinciples of flight.

1. Explain the relationship between the gravity, lift, thrust, and drag that must exist for an aircraft to fly at a constant altitude and a constant airspeed. (15-5—9)

2. The term "airfoil" is usually applied to what parts of an aircraft? (15-11)

3. State Bernoulli's principle. (15-13)

4. Is all of the air met by an airfoil used for lift? (15-16)

5. Explain why an aircraft stalls. (15-19)

Section 16

Objective: To be able to recognize and identify the classes and types of damage and explain why certain general structural repairs are necessary.

1. Explain what is included in "sizing up" the job. (16-3)

2. Why must you work carefully when forming heat-treated and cold-worked alloys? (16-8)

3. How is the actual thickness of a piece of material being repaired measured? In thousandths or hundredths of an inch? (16-14)

4. What is meant by the term "bearing" strength of a rivet? (16-17)

5. Why is it necessary to keep the weight of all repairs to a minimun? (16-22)

6. Name the four clases of damage. (16-30—33)

7. How can nonclad aluminum metal be made corrosive resistant? (1-38)

8. Name the conditions that must exist for corrosion to occur. (16-40)

9. Salt collecting on metal surfaces will result in what corrosive action? (16-44)

10. If uniform etch corrosion is allowed to continue how will the surface become? (16-49)

11. How do you identify the early stages of exfoliation corrosion? (16-52)

12. When substituting parts to prevent corrosion what factors must you consider? (16-58)

13. Expalin the stages of fatigue corrosion. (16-64)

14. When should all equipment be isnpected for corrosion? (16-66)

15. You have inspected an aircraft and found extensive corrosion on the empennage. What action do you take? (16-68)

16. Forces act on the aircraft whether it is on the ground or in ____________ . (16-73)

17. When the aircraft is in flight, which aircraft structures have forces acting on them in a direction opposite to the forces on the ground? (16-74)

18. What is meant by the net area of a surface? (16-78)

19. All holes in an aircraft structure are tightly plugged with a plug of stronger material than the drilled member. Which stress will the plug transfer across the hole? (16-79)

Section 17

Objectives: To be able to select and identify correct repair material; to describe how selected specific structural repairs are completed; and to explain why the repair was made that way.

1. You are to make a flush skin repair. If the direction of stress is known, which patch do you install? (17-6, 9)

2. You are to make a panel repair. You trim the damage and have less than 8½ manufacturers rivet diameters of material remaining inside the member. Describe the patch to install. (17-14)

3. Expalin the purpose of seals and baffles. (17-18, 23)

4. Why are baffles ususally made of aluminum? (17-24)

5. Why are trim tabs, balance tabs, and servo-tabs used? (17-30)

6. What is the purpose of a stringer? (17-34)

7. Explain the use of reinforced openings. (17-38)

8. When should metal collars be used on self-locking nuts? (17-41)

9. Why must stringers formed by machine process be heat treated? (17-46)

10. When you repair a stringer, what three things must you consider? (17-49)

11. Half the cross-sectional area of a bulkhead is damaged. How do you repair the damage? (17-61)

12. What kinds of repair are usually made on spars? (17-66)

13. What are the three types of ribs used on wings and stabilizers? (17-71)

14. How do leading edge sections construction vary? (17-74—75)

15. Describe the types of leading edge damage. (17-80)

16. Explain how you repair an overlapped skin trailing edge. (17-87)

Section 18

Objectives: To be able to identify and select the correct seal for the job at hand and explain why the selection was made and how to inspect the finished work; and to explain how to safely repair a metal fuel tank.

1. Explain the difference between the levels of sealing. (18-4)

2. Which level of sealing would you select for a fuel tank repair and why? (18-6)

3. How is the firewall sealant used to restrict the passage of flame through the seal plan classified? (18-9)

4. What is an injection seal? (18-14)

5. What is a fillet type seal? (18-14)

6. Explain how to check a pressure seal for leaks. (18-20)

7. Why do you clean all surfaces immediately before you apply the sealing compound? (18-27)

8. Explain the difference in the application of a fillet seal and inection seal. (18-35, 36)

9. Explain the difference in the curing action of a one-part and a two-part aerodynamic smoother. (18-41)

10. Explain how to apply an aerodynamic smoothing compound. (18-47)

11. Why do you use an explosimeter before you work inside a metal fuel tank? (18-52)

CHAPTER 5

Section 19

Objective: To be able to differentiate between static and dynamic balance and to demonstrate an understanding of basic balancing terms and principles by solving balancing problems.

1. Explain the difference between static balance and dynamic balance. (19-1, 2, 6)

2. Explain the difference between moment arm b and c. (19-7)

3. Explain the meaning of the formula $M = b \times W_R$. (19-7)

4. If you are to seeaw with your child, how far must you sit from the fulcrum? Your child weighs 60 pounds and is seated 5 feet from the fulcrum. You weigh 150 pounds. (19-12, 13)

5. You have added 0.125 pounds of weight 12 inches aft of the hinge centerline of a control surface. The rebalance weight is to be mounted 6 inches forward of the hinge centerline. What is the required weight of the rebalancing weight? (19-13)

Section 20

Objectives: To be able to explain why one method or control surface balancing is selected over the others and differentiate between the ways to determine net W_R; and to name the materials suitable for use as balance weights.

1. What is the advantage of the calculation method of balancing a control surface over the other methods? (20-5)

2. Explain the difference in the procedure for determining net W_R in the calculation method and the scale method of balancing control surfaces. (20-6–12)

3. When you use the scale method of balancing control surfaces, why must you know net W_R rather than gross W_R? (20-14)

4. What is the advantage of the component method of balancing control surfaces over the other methods? (20-18)

5. Name the materials that may be used for balance weights. (20-19)

MODIFICATIONS

Pages 19 - 20 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 2

Section 6

1. The manufactured head is formed when the rivet is made. The shop head on the opposite end of the rivet is formed when the rivet is used or installed.

2. This rivet is ready for use as received and needs no further heat-treating or annealing.

3. The 1100 rivet is very soft and is used in nonstructural parts where strength is not a factor. The 2117T rivet is used more than any other rivet for riveting aluminum alloy structures. The 2017T and 2024T rivets are used where more strength is needed than can be obtained from the 2117T rivet. The 5056 rivet is used to rivet magnesium alloy structure.

4. Storing these rivets in an electric refrigerator slows the age-hardening process.

5. If the joint remains dry, nothing happens. However, in the presence of moisture, an electric current flows. This current flow results in the dissolution of the less noble of the two metals. You may want to restudy the discussion of corrosion in an earlier volume to refresh your memory.

6. Countersunk-head rivets offer less resistance to the slipstream than universal-head and help to minimize turbulent airflow.

7. The markings on the heads of rivets indicate the material of which the rivet is manufactured. The markings are also used to classify the characteristics of rivets.

8. An MS20470DD5–7 rivet is a universal rivet. The composition of the rivet is aluminum alloy 2024T, the diameter is 5/32 inch, and the length is 7/16 inch.

Section 7

1. In the hand squeeze riveter, compression is supplied by hand pressure. In the pneumatic squeeze riveter, compression is supplied by air pressure.

2. Drop one or two drops of oil in the air inlet.

Section 8

1. The minimum diameter of the rivet is 1/8 inch.

2. Rivet pitch is the distance between the centers of neighboring rivets on the same row. Transverse pitch is the perpendicular distance between rivet rows.

3. In a single-row layout, determine the edge distance at the end of each row, then lay off the rivet pitch distance between rivets. In a tow-row layout, lay off the first row as just described. Place the second row a distance equal to the transverse pitch from the first row. Finally, lay off the rivet spots in the second row so they fall midway between those in the first row. In a three-row layout, lay off the first and third rows. Then use a straight edge to determine the second row rivet spots.

4. Use an expanding bucking bar.

5. A dimple is made around a rivet hole so the top of a countersunk rivet will be flush with the top of the metal.

6. When working on soft mentals, use a twist drill that has an included angle of 90°.

7. Some of the causes of elongated wells include: oversized rivet holes, undersized countersink pilots, chattering caused by improper use of the countersink or by a countersink in poor condition, countersink not running true in the chuck of the drill, and tipping the drill.

8. The advantages of coin dimpling include: improved configuration of the dimple, a more satisfactory aerodynamic skin surface, no radial and circumferential cracking, a stronger and safer joint, and identical dies may be used during dimpling.

9. Control panels.

10. Before you dirve rivets, all the rivet holes must line up, the shavings and burrs must be removed, and the parts fastened together.

11. Hammering changes the crystaline structure of the rivet or the material around it. This causes the joint to lose some of its strength.

12. Hold the rivet set on a pneumatic rivet gun at right angles to the work to prevent damage to the rivet head or surrounding work.

13. For large assemblies where the tool may be moved in relation to the work.

14. A small, round dot about the size of a pinhead on the head of the rivet indicates that the mciro-shaver is adjusted properly.

15. Shear failure is a breakdown of the rivet shank by forces that cuts the rivet shank in two. Bearing failure is the crushing or buckling of the material at the edge of the rivet hole. Head failure is distortion of the rivet head.

16. The rivet head will break away and climb the drill.

Section 9

1. They are about 60 percent lighter than bolts of the same diameter and require about 20 percent as long to install as the bolt, washer, and nut combination.

2. When you drive a pin rivet from the collar end, the bucking bar is placed against the rivet head and the collar is placed over the protruding rivet end. The rivet set and gun are placed over the collar. When you drive a pin rivet from the head end, the rivet set is placed in the bucking bar and the bar is placed over the collar on the protruding end of the rivet. A flush type rivet set is used in the pneumatic hammer and the pressure is applied to the head side.

Section 10

1. The two parts of a self-plugging rivet are a rivet head with a hollow shank or sleeve and a stem that extends through the hollow shank.

2. The stem is pulled into the shank, the mandrel portion of the stem forces the rivet shank to expand, and the stem breaks off at the groove on the stem.

3. A hammering force is not required to install the rivet.

4. The manufacturer of the rivet being installed.

5. Use a rivet shaver.

6. Heads of installed self-plugging rivets are inspected to insure they fit tightly against the metal.

7. When the stem is pulled into position, the manufactured and shop heads tighten against the material, the locking collar is forced into position, and the rivet stem snaps off.

8. The grip range on both rivets is measured in thousandths of an inch.

9. Basically the same as installing friction lock rivets.

10. It has a hollow center after it is installed.

11. Closed-end Rivnuts are used in pressurized compartments.

12. Minimum grip lengths of Rivnuts is indicated by a plain head.

13. If the material is too thick to use the keyway cutter, use a small round file.

14. Use key type Rivnuts whenever screws are to be inserted.

15. The shank of an installed Rivnut should fit snugly in the hole.

16. Yes, Dimpling in sheets of average gage limits the grip range of the rivet.

17. The installation is incomplete without a plug or screw. The Rivnut does not develop its full strength when left hollow.

18. These parts are anodized to resist corrosion.

395

19. Insert the Lock-Skru tool so the blade extends through the barrel slot and the driver sets firmly in the head slot.

20. The shear strength of a Deutsch rivet is 75,000 psi minimum.

21. The locking action of the ring on top of the rivet head is destroyed.

Section 11

1. The types of lockbolts are pull, stump, and blind types.

2. Use stump lockbolts in installations where space does not permit use of pull type lockbolts.

3. By measuring the thickness of the material with a hook scale inserted through the hole.

4. The lockbolt collar should be swaged substantially throughout the complete length of the collar.

Section 12

1. The F indicates a flush head. The 6½ indicates the diameter in 16ths of an inch. The .50 indicates the length in 100ths of an inch.

2. The style II trunlock fastener has such an assembly.

3. The style III turnlock fastener has such a cross-pin.

CHAPTER 3

Section 13

1. They are usually used in the assembly and repair of the aircraft where riveting or welding is unsuitable. They are also used where high tension is found.

2. A nut is needed on the bolt but is not necessary on all screw installations.

3. A bolt has a long clearly defined grip length. A screw has no clearly defined grip length since the entire shank of the screw is usually threaded.

4. Cadmium- or zinc-plated, non-corrosion-resistant steel, corrosion-resisting steeel, and anodized aluminum alloy.

5. The washer is used to provide an adequate surface for the head.

6. When power is applied, the bolt is turned while the nut is held. The sleeve is drawn over the taper. The sleeve is expanded forming the blind head against the surface of the inner structure.

7. Non-self-locking nuts are safetied by external locking devices such as lock nuts, cotter pins, or safety wire. Self-locking nuts contain the locking devices as an integral part of the nut.

8. You would be using a non-self-locking nut.

406

9. You would find self-locking nuts in a section of the aircraft subject to severe vibration.

10. The slot is wider so it can be narrowed and the insert compressed when the nut is tightened.

11. The fiber locking collar is not threaded and the insert diameter is smaller than the largest diameter of the threaded portion of the nut. When the nut is screwed onto a bolt, it turns as an ordinary nut until the bolt reaches the fiber collar. When the bolt is screwed into the collar, the action tends to push the fiber upward. Since the collar tends to push downward, the result is a locking action.

12. If a sharp blow with a 12- or 14-ounce hammer is required to move the bolt, the fit is a tight-drive fit. If the bolt moves when you hold a hammer handle against the head and press by the weight of your body, the fit is a light-drive fit.

13. Bolts do not become swaged to fill up elongated or oversize holes as do rivets; therefore, exact size holes are needed for the bolts to carry their shear load.

14. A torque wrench should be used on the nut to avoid stripping threads, cracking nuts, or snapping bolts and to assure that all bolts carry their share of the load.

15. Plain, lock, and special washers.

16. They are used under AN hex nuts as shims. They are also used under lock washers to prevent damage to surfaces.

17. Use the plain washer.

18. A plain wahser is required undernetath the lcok washer to prevent gouging the skin.

19. Machine screws are general purpose screws.

20. AN501C–416–8 would be the corrrct code number.

21. The prime objective of all welding is the joining of two pieces of metal without loss of strength.

22. Seam welding is accomplished by the use of wheels. These wheels are electrodes, and, as the work is pulled between the wheels, welds are made. The spot welder contains cylindrical rod electrodes, and each welding cycle makes only one weld.

23. On parts and assemblies that do not fit into the throat of conventional machines.

CHAPTER 4

Section 14

1. The skin acts as the principal part of the airframe and carries the primary stresses. The weakness or difficulty is maintaining enough strength and staying within weight limitations.

2. They are the main lengthwise members of the fuselage and carry most of the stress.

3. The monospar wing has only one main longitudinal structure. The multispar has more than one main longitudinal structure. The box beam has two main longitudinal structures connected by bulkheads.

4. This type construction consists of a web and cap strips with stiffeners added for additional strength.

5. Fairing is used to prevent turbulence in the airflow or to smooth out the airflow over the angles formed by the wings and other structural units with the fuselage. Fairing also reduces drag.

6. The lateral axis is controlled by the elevators. The longitudinal axis is controlled by the ailerons. The vertical axis is controlled by the rudder.

7. Ground-adjustable trim tabs are usually narrow strips of aluminum alloy attached to the trailing edge of a control surface and can be adjusted only when the aircraft is on the ground. Flight-adjustable trim tabs are recessed into the trailing edge of a control surface and may be adjusted in flight.

8. Elevons are control surfaces which combine the functions of the elevators and the ailerons. Flaperons are flaps which also act as ailerons.

Section 15

1. For an aircraft to fly at a constant altitude, lift must equal gravity; For an aircraft to fly at a constant airspeed, thrust must equal drag.

2. The term "airfoil" is usually applied to the wings and empennage.

3. As the speed of air moving over a surface increases, the pressure on the surface decreases proportionately.

4. No. Air resistance is converted into both lift and drag. Drag hinders forward motion.

5. When the angle of attack becomes so great that air no longer clings to the top of the wing and turbulence slows down the speed of the airflow, the pressure differential above and below the wing decreases. When this differential becomes so little that the wing looses the lift required to maintain altitude, the aircraft stalls.

Section 16

1. "Sizing up" the job includes an estimate of the best type and shape of patch to use; the type, size, and number of rivets to use; and the strength, thickness, and kind of material required for the repair.

2. These alloys crack easily.

3. In thousandths of an inch.

4. Bearing strength is the amount of tension required to pull a rivet through the edge of two sheets riveted together or to elongate the hole.

5. By adding a little excess weight in each repair, you will eventually unbalance the aircraft so much that the trim and balance tabs will require adjustment.

6. The classes of damage are: negligible damage repairable by patching, damage repairable by insertion, and damage necessitating replacement of parts.

7. Nonclad aluminum can be made corrosive resistant by anodizing or chemically treating and by painting with an organic finish.

8. For corrosion to occur there must be: something that corrodes the metal, a cause, a continuous liquid path, and a conductor to carry the flow of electrons from the anode to the cathode.

9. It will increase electrical conductivity of any moisture present and accelerate corrosion.

10. The surface will become rough and possibly frosted in appearance.

11. This corrosion is a form of intergranular corrosion and is recognized by a "lifting up" of the surface grains of the metal.

12. The structural strength of the aircraft/missile must not be endangered by substituting incorrect parts to prevent corrosion.

13. First, the combined action of corrosion and cyclic stress damages the metal by pitting and eventually cracks the metal . Second, metal fatigue spreads the crack.

14. Inspect all equipment for corrosion at each periodic inspection.

15. Remove the corrosion, and apply the specified corrosion preventatives.

16. Flight.

17. The forces on the wingtips and wing surfaces are in the opposite direction.

18. Net area of a surface is the gross area minus that removed by drilling holes or making other changes in the section.

19. The stress of compression.

Section 17

1. Use the elongated octagonal patch.

2. Use a patch which extends over the members plus an extra row of rivets along the outside of the members.

3. Aircraft seals are used to keep air and other gases within their proper channels. Baffles are used in air systems to direct and control the flow of air.

4. Baffles are usually made of aluminum so they can be shaped and welded more easily.

5. They provide additonal stability or control or help to activate the larger control surfaces.

6. Stringers are used to give stiffness and additional strength.

7. Reinforced openings provide access to internal parts of the aircraft and are installed to make inspection, maintenance, and repair easier.

8. Metal collars should be used if they are to be exposed to high temepratures.

9. Stringers formed by machine process must be hardened by heat treatment to obtain their maximum strength.

10. You must consider: (1) location of the stringer in the aircraft, (2) location of damage to the stringer, and (3) extent of damage to the stringer.

11. Remove the entire damaged section and make a splice repair in the area.

12. The two kinds of repair are web repairs and cap strip repairs.

13. The three types of ribs used are trussed rib, soild web, and lightening hole.

14. The construction of leading edge sections varies with the type of aircraft for which it is designed.

15. One type of leading edge damage is caused by contact with flying objects such as flak, pebbles, birds, etc. The other type of damage is carelessness caused by maintenance personnel while the aircraft is on the ground.

16. Use a reinforcement patch of sheet stock which is joggled to conform to the contour of the overlapping skins.

Section 18

1. An absolute seal requires sealing of all seams, holes, slots, and joggles which are fastened to the seal plane. (Seal everything.) For an extensive seal, seal everything except (1) protruding rivets, (2) standard flush rivets in dimpled holes, (3) standard flush rivets in countersunk holes if driven high and shaved, or (4) upset heads of dural rivets. For an intermediate seal, seal everything except the fasteners. For limited sealing, seal everything except the seams and fasteners.

2. Use an absolute seal because there must be no leakage in the fuel tank.

3. Sealant is classified as absolute, intermediate and limited, according to the area in which the fire wall sealant is used.

4. An injection seal is filling of holes or channels by forcing sealant into a cavity to obtain a primary or backup seal.

5. A fillet is a bead of sealant applied along structural junctions or seams.

6. Pressurize the section to the pressure specified in the applicable tech order. Apply a soapless bubble fluid to the outside of all joints and seams in the suspected area to find the general area of leakage. Then pinpoint the leak from the inside by passing the free end of a stethoscope or similar listening device along the seams in the leakage area. The leak will cause a change in sound when the listening device passes over it.

7. Many types of impurities form a film over metal which is not visible, but prevents proper adhesion of the sealant. The only way you can be sure the area is clean is to clean it just before you apply the sealant.

8. A fillet seal is applied by hand or with a pressure gun and a wooden or plastic tool to the parting line between two attached parts. An injection seal is applied with a pressure gun. The injection seal is applied to all confined holes, slots, and joggles through drilled holes.

9. One-part compounds use chemical action to control the speed of curing.. Two-part compounds use a filler and an accelerator to control the curing time.

10. Clean the surface and dry it. Use a putty knife or spatula to apply the smoothing compound. Work the compound over the area evenly. Force enough into slots, crevices, or heads of recessed screws to allow for shinking.

11. Use this meter to determine the fuel vapor concentration of air insdie the tank. This is a safety precaution.

CHAPTER 5

Section 19

1. Static balance is the tendency of an object to remain stationary when supported from its own center of gravity. Dynamic balance is that condition in a rotating body when all rotating forces are balanced so that the body does not vibrate while in motion. Static balance is concerned with a rotating body.

2. Moment arm b is the measured distance from the hinge centerline to the center of the patch. C is the measured distance from the hinge center line to the center of the rebalance weight.

3. Moment (M) is equal to the distance from the hinge centerline of the control surface to the center of the applied repair multiplied by the weight of the repair.

4. Sit 2 feet from the fulcrum.

5. Use a 0.25 pound weight.

Section 20

1. The surface does not have to be removed from the aircraft.

2. In the calculation method, net W_R is determined by subtracting the weight of the material removed (from the damaged area) from the weight of the material added. In the sacle method, net W_R is determined by either (1) subracting the weight of the support fixture assembly from total weight reaction, or (2) setting the scales to zero after the adjustable support fixture has been mounted.

3. You need to know net weight reaction to use the tables in technical orders.

4. All components balanced by this method are considered to be interchangeable with other components on alternate complete units.

5. Rebalance weights may be made of lead, fan steel, 4130 steel, or corrosion resistant steel.

STOP–

1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.

2. USE NUMBER 1 PENCIL.

53450 03 26

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

403

Chapter 2

17. (303) The 2117–T4 rivet is in wide demand for all of the following reasons *except* that it

a. needs no further annealing.
b. has a high resistance to corrosion.
c. needs no further heat treating.
d. can be used where the greatest strength is needed.

18. (303) Which of the following aluminum alloys are the least likely to corrode when riveted together?

a. 3003 and 2017.
b. 3003 and 7075.
c. 3003 and 5052.
d. 3003 and 2117.

413

19. (303) Which statement is true concerning the squeeze method of riveting?

a. This method is limited to use over the edges of sheets or assemblies.
b. Riveting with a squeezer requires two operators.
c. All types operate on hydraulic pressure.
d. Both jaws are movable.

20. (304) If you space rivets too far from the edge of the sheet, the sheet is likely to

a. crack.
b. turn up at the edges.
c. bulge around the rivets.
d. pull away from the rivets.

21. (304) Transverse pitch is usually equal to what percent of the rivet pitch?

a. 25 percent.
b. 50 percent.
c. 75 percent.
d. 85 percent.

22. (305) A twist drill for use on hard metals should have an included angle of

a. 45°.
b. 90°.
c. 118°.
d. 120°

23. (306) If the bucking bar used in driving rivets is too heavy, the material may

a. become marred.
b. bulge toward the shop head.
c. kink into a depression.
d. bulge away from the shop head.

24. (305) Corrosion-resistant steel is cold dimpled because,

a. it is tough.
b. it has low formability qualities.
c. hot dimpling may produce hard spots in the metal.
d. the temperature range of the heating unit is not high enough to affect dimpling.

25. (306) If the rivet you are driving is going "clubhead," you should

a. move the bucking bar across the rivet in the opposite direction.
b. use the process called coordinated bucking.
c. remove the rivet and start over.
d. use reverse riveting.

26. (306) Which method od driving a rivet produces the most uniform and balanced type of shop head?

a. Hand driving.
b. Squeeze riveting.
c. Pneumatic driving.
d. Reverse riveting..

27. (306) When you hand drive rivets, you should keep hammer strokes to a minimu because too much hammering
a. causes undue corrosion.
b. deforms the rivet head.
c. causes the material to buckle.
d. changes the crystaline structure of the rivet or material.

28. (306) A microshaver is used when a repair requires that

    a. stationary equipment be used.
    b. the tool be moved in relation to the work.
    c. countersunk rivets be removed for replacement.
    d. all countersunk rivets be driven within a specific tolerance.

29. (307) Which statement is correct concerning Hi-Shear pin rivets?

    a. They are used only in shear applications.
    b. They are used where the grip length is less than the shank diameter.
    c. They are approximately twice as strong as solid shank rivets.
    d. They require about one-half as much time for installation as a bolt, nut, and washer combination.

30. (307) It is sometimes necessary to spot-face the area under the head of a Hi-Shear rivet to

    a. allow the rivet head to fit tight against the material.
    b. make the removal of the rivet easier.
    c. swage the collar onto the rivet.
    d. make a seat for the collar.

31. (308) To rivet material made of magnesium, you should use a self-plugging (friction lock) rivet with which of the following material combinations?

    a. Stem steel and sleeve steel.
    b. Stem 2017 aluminum alloy and sleeve 2117 aluminum alloy.
    c. Stem 2017 aluminum alloy and sleeve 5056 aluminum alloy.
    d. Stem 5056 aluminum alloy and sleeve 2117 aluminum alloy.

32. (308) Self-plugging (friction lock) rivets are designed so that installation requires.

    a. a bucking bar.
    b. one person.
    c. a hammering force.
    d. that the work be accessible from both sides.

33. (309) When a pulling force is exerted on the stem of a self-plugging (mechanical lock) rivet,

    a. the rivet head is tightened against the material.
    b. an inner anvil forces the locking collar into position.
    c. the rivet stem snaps off even with the head of the rivet.
    d. all of the above operations take place.

34. (309) For efficient operation of the CP350 blind rivet tool, the range of line pressure should be from

    a. 80 to 90 psi.
    b. 90 psi to 110 psi.
    c. 80 to 110 psi.
    d. 90 to 100 psi.

35. (309) Cherry Lock rivets are installed by the use of the

    a. H–610 pulling head.
    b. CP350 rivet tool.
    c. CP351 pull gun.
    d. CP353 pull gun.

36. (309) Which statement concerning Rivnuts is correct?

a. Rivnuts are used principally on primary structures.
b. Rivnuts without keys are used for service as nut plates.
c. Closed-end Rivnuts must be used in pressurized compartments.
d. Keyed Rivnuts are used where no torque loads are imposed.

37. (309) When you install Cherry Lock rivets, be sure that

a. the correct grip range is selected.
b. the pressure setting is correct for each rivet diameter.
c. you do not hold pressure against the head of the rivet.
d. the rivet stem snaps at a break-off groove in the stem.

38. (309) The Dill Lok-Skru, Dill Lok-Rivet, and Rivnuts are alike in that they all

a. come in three parts.
b. are internally threaded.
c. must be tapped internally for fastening an accessory.
d. require the same amount of clearance on the blind side.

39. (309) What is the most important factor to be considered when you are selecting Rivnuts?

a. Presence or absence of a key.
b. Condition of Rivnut end.
c. Style of the head.
d. Grip range.

40. (309) If the last two or three numbers in the code number for a Rivnut are divisible by 5, the Rivnut has

a. a flat head.
b. a countersunk head.
c. an open end and a key.
d. a closed end and is keyless.

41. (309) The ideal bulge on the blind side of a properly installed Rivnut is

a. a smooth bulge in the rivet shank with the last two threads squeezed together to lock the plug in place.
b. a bulge between the first thread of the rivet and the lower edge of the riveted material.
c. a round bulge in the rivet shank at the manufactured head end of the rivet.
d. an oval bulge in the rivet shank at the shop head end of the rivet.

42. (309) One of the main restrictions to the use of the Deutsch rivet is that

a. it has low shear strength.
b. its head must be shaved or milled.
c. no bucking bar is used to take up the shock of driving.
d. it cannot be installed without going all the way through the second piece of material.

43. (309) The two parts of the Deutsch rivet are the

a. union and the collar.
b. sleeve and the collar.
c. steel collar and the copper sleeve.
d. stainless-steel sleeve and the hardened steel drive pin.

44. (309) If a Deutsch rivet is driven into a tight hole, what tool would you use to seat it against the material?

a. Hot chisel.
b. Cold chisel.
c. Hollow drift punch.
d. Solid drift punch.

45. (309) The radial dash marks on the head of a Rivnut indicate the

a. grip length.
b. head type.
c. rivet diameter.
d. alloying material.

46. (310) Alloy steel lockbolts may be used to replace steel Hi-Shear rivets, solid steel rivets and

a. stainless-steel rivets.
b. blind rivets of all diameters.
c. blind rivets of the same diameter.
d. AN bolts cf the same diameter and head type.

47. (310) To install bliind type lockbolts, you will need a

a. bucking bar.
b. special pneumatic pull gun.
d. swaging set.
d. pneumatic riveting hammer.

48. (310) The stud length of the style I turnlock fastener is measured in

a. hundredths of an inch from end to end.
b. sixteenths of an inch from the top of the stud to the top of the spring hole.
c. hundredths of an inch from the bottom of the spring hole to the head of the stud.
d. sixteenths of an inch from the head of the stud to the opposite end of the stud.

49. (310) When you prepare the hole to install style II turnlock fasteners, you should burr and sand the edges of the hole to

a. work harden the material.
b. make removal of the fastener easier.
c. achieve a better fit between the stud and the grommet.
d. keep the edges from cracking during dimpling operations.

50. (310) The cross-pin of the turnlock fastener–style III is manufactured from

a. case-hardened steel.
b. high-carbon steel.
c. chrome-vanadium steel.
d. high-strength aluminum alloy.

Chapter 3

51. (311) Which statement concerning bolts and screws is *not* correct?

a. The threaded end of a screw is always pointed.
b. Both are made of aluminum alloy or steel.
c. The threaded end of a bolt is always blunt.
d. A screw is always tightened by turning its head.

52. (311) Which of the following bolts is never used in tension?

a. Internal wrenching bolt.
b. Clevis bolt.
c. Jo-Bolt.
d. Eyebolt.

53. (311) Which of the following identifies standards and specifications applied to common bolts?

a. F, FS, FP, and MS.
b. AN, NAS, MS, and AMS.
c. MS, AMS, F, and FA.
d. MS, F, P, and FA.

54. (311) Which statement is *not* true concerning aircraft nuts?

a. They come with the bolts when bolts are ordered.
b. They may be obtained with right-hand or left-hand threads.
c. Most of them are Air Force-Navy Standard.
d. They have no identifying marks or letters.

55. (311) Which of the following aricraft nuts are self-locking?

a. Castle nuts.
b. Light hexnuts.
c. Elastic stop nuts.
d. Castellated shear nuts.

56. (312) If a particular bolt, nut, and washer installation requires 60-pound-foot torque, you should use a

a. 60-pound force at the end of any bar.
b. 60-pound force at the end of a 2-foot wrench.
c. 30-pound force at the end of a 12-inch wrench.
d. 30-pound force aththe end of a 24-inch wrench.

57. (312) If you are going to replace an alloy steel bolt with a screw, what type screw should you use?

a. Drive.
b. Machine.
c. Structural.
d. Self-tapping.

58. (312) To attach a nameplate to a casting, you should use a

a. turnlock fastener, style I.
b. self-tapping screw.
c. solid shank rivet.
d. Jo-Bolt.

Chapter 4

59. (313) As strengthening devices, what are the most outstanding structural members in the fuselage?

a. Formers.
b. Stringers.
c. Station webs.
d. Frame assemblies.

60. (313) In general, wing construction is based on how many fundamental designs?

a. 1.
b. 2.
c. 3.
d. 4.

61. (313) The principal structural members of the wing are the

a. ribs.
b. spars.
c. stringers.
d. stiffeners.

62. (313) The main group of flight control surfaces includes

a. elevators.
b. balance tabs.
c. servo tabs.
d. flaps.

63. (314) Lift and drag (the two forces into which air resistance is converted) depend upon

a. air density.
b. the angle of attack.
c. the speed of the airfoil.
d. all of the above factors.

64. (315) To determine the number of rivets to use to repair a structural part of an aircraft, you should

a. consult TO 1–1A–1.
b. refer to a similar splice made by the manufacturer.
c. multiply the length of the break by the width and dive by 3.
d. multiply the thickness of the skin to be repaired by 75,000 and divide by 3.

65. (315) How is the length of a break to be repaired measured?

a. Horizontal to the line of damage.
b. Vertical to the line of damage.
c. Perpendicular to the fuselage.
d. Perpendicular to the direction of the general stress running through the damaged area.

66. (315) What is shear strength?

a. The assumed stress load value increased by 35 percent.
b. The amount of force required to cut a rivet holding two or more sheets of material together.
c. The assumed stress load value increased by a safety factor of 25 percent.
d. The amount of tension required to pull a rivet through the edge of two sheets riveted together.

67. (315) Damage to the structure of an aircraft which can be repaired by cutting away the damaged section, replacing the removed section with a like section, and securing the section with splices is classified as

a. negligible damage.
b. damage repairable by patching.
c. damage repairable by insertion.
d. damage necessitating replacement of parts.

68. (316) What technical order contains detailed information on corrosion detection, removal, and application of corrosion preventatives?

a. TO 1–1–2.
b. TO. 1–2–1.
c. TO 01–3–4.
d. TO 02–3b–3.

69. (316) Which of the following materials used in airframe structures are most resistant to corrosion?

a. Painted aluminum metals.
b. Pure nickel-plated metals.
c. Aluminum anodized metals.
d. Aluminum alloy sheets coated on both sides with pure aluminum.

70. (316) Which of the following types of stresses in an aircraft are called combination stresses?

a. Tension.
b. Shear.
c. Torsion.
d. Compression.

71. (316) The most common effect of corrosion on aluminum and magnesium alloys is called

a. pitting corrosion.
b. galvanic corrosion.
c. intergranular corrosion.
d. uniform etch corrosion.

72. (316) Alloys that owe their corrosion resistance to passivity are particularly susceptible to

a. climatic changes.
b. corrosion due to heat.
c. corrosion due to stresses.
d. accelerated corrosion within crevices.

73. (316) When it is not practical to use rivets, bolts, or other fasteners made of the same material as the main structure, you should select materials which

a. are lower in the chart of metals.
b. are most corrosion-resistant.
c. are higher in the chart of metals.
d. have the least weight factor.

74. (316) Which of the following single stresses is the *least* like shear?

a. Bending.
b. Compression.
c. Torsion.
d. Tension.

75. (316) Fatigue corrosion is caused by the

a. combined effects of cyclic stress and corrosion.
b. simultaneous effects of tensile stress and corrosion.
c. reaction with each other of adjacent grains of different elements when in contact with an electrolyte.
d. contact of two or more areas of a metal surface with different concentrations of the same solution.

76. (317) An elongated octagonal patch has all of the following characteristics *except* that it

a. is simple to lay out.
b. eliminates dangerous stress concentrations.
c. is ideal to use in places where the direction of stress is unknown.
d. provides a good concentration of rivets within the critical stress area.

77. (317) Under which of the following conditions would you install a three-row round patch?

a. A two-row patch will not have enough strength.
b. The direction of stress is known and the size of the patch is large enough to accommodate the third row of rivets.
c. The damage extends from the adjacent stringer to the bulkhead and is so extensive that the elongated patch cannot be used.
d. The required number of rivets is large enough to cause the pitch distance to be smaller than the minimum for a two-row patch.

78. (317) Before repairing a damaged extruded section, you should first locate an illustration of a similar repair in

a. TO 1–1A–1.
b. the factory manual.
c. the applicable –2 technical order.
d. the applicable –3 technical manual.

79. (317) What are the three types of ribs?

a. Bulkhead rib, former rib, and circumferential rings.
b. Trussed rib, solid web, and lightening hole.
c. Longeron rib, stringer rib, and spar rib.
d. Zee rib, extruded rib, and channel rib.

80. (317) Corrosion in the trailing edge of a wing is usually caused by

a. dissimilar metals.
b. poor workmanship.
c. improper installation.
d. clogged drainage holes.

81. (318) Which of the following falls in the absolute sealing classification?

a. Cabin area sealing.
b. Liquid fuel sealing.
c. Fuel vapor sealing.
d. Aerodynamic balance sealing of the empennage.

82. (318) What is the most efficient seal used on aircraft?

a. Fillet.
b. Re-entrant.
c. Injection.
d. Faying surface.

83. (318) To insure aerodynamic smoothness when you repair a damaged leading edge of a wing, which type of seal should you use?

a. An acid-resistant seal at the limited level.
b. A pressurized seal at the absolute level.
c. A weather seal at the intermediate level.
d. A fuel seal at the extensive level.

84. (318) If a one-part sealant does not go on smoothly, easily, and evenly, you should

a. add thinner.
b. throw it away.
c. add accelerator.
d. whip air into the sealant.

85. (318) The time required to cure sealants is dependent upon all of the following factors *except* the

a. worklife of the sealant.
b. relative humidity.
c. ambient temperature.
d. method used to apply the sealant.

86. (318) Which of the following patches are you most likely to use on an interior metal fuel tank?

a. Splice.
b. Flush.
c. Overlapping.
d. Butt-welded.

Chapter 5

87. (319) Which choice defines the hinge centerline?

a. The axis aboaut which the control surface rotates.
b. That point at which the surface can be balanced in any position.
c. The point of laod concentration.
d. That point at which all forces acting on a body in motion are balanced equal.

88. (319) When you repaired a control surface, you added 0.125 pound to the surface. This weight was added 6 inches aft of the hinge centerline. The balance weight is to be installed 3 inches forward of the hinge centerline. How heavy must the balance weight be to rebalance the surface?

a. 0.125 pound.
b. 0.25 pound.
c. 0.375 pound.
d. 0.50 pound.

89. (320) Which method of rebalancing control surfaces can be accomplished without removing the surface from the aircraft?

a. Scale.
b. Component.
c. Calculation.
d. Trail weight.

90. (320) Which method of rebalancing control surfaces is a combination of two other methods?

a. Scale.
b. Component.
c. Calculation.
d. Trial weight.

53450 04 1268

CDC 53450

AIRFRAME REPAIRMAN/TECHNICIAN

(AFSCs 53450 and 53470)

Volume 4

Specialized Repairs

2-3

Extension Course Institute

Air University

Preface

IN PREVIOUS volumes. your study of airframe repairs has been limited primarily to repairs involving the cutting and forming of sheet and extruded metal stock and fastening of repair parts with rivets. lock bolts. and other hardware. However, many parts of our modern aircraft are made of plastic and various types of fiberglass. Also. the need for greater strength and less weight in aircraft design is causing ever-increasing use of metal bonded honeycomb panels. Repairs of fiberglass and metal bonded honeycomb are quite different from ordinary skin and structural repairs. Inspection and repairs of these materials require special knowledges and skills; so the work is usually assigned to only highly qualified 5- and 7-skill level repairmen. Obviously. you need these specialized knowledges to upgrade. and that is why we have prepared this fourth volume of your CDC.

You will find that this volume contains instruction in the inspection and replacement of transparent sections in enclosures; inspection. repair. and replacement of mat molded. laminated. and various sandwich type fiberglass structures; and inspection and repair of metal bonded honeycomb panels. Instruction includes removal of damaged materials. mixing of adhesives and potting compounds. installation of glass cloth laminate and core materials. heat-curing processes. and finishing of repair surfaces. You will also find information you need for inspection methods and test equipment. The last chapter is devoted to repair of aircraft cables and plumbing including inspection. use. and care of production tube benders and flaring machines.

Remember that specific procedures for accomplishing aircraft structural repairs and the maintenance of tools and equipment must be inaccordance with applicable maintenance manuals.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement. send them Tech Tng Cen (TSOC), Chanute AFB. IL 61866.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development. Study Reference Guides. Chapter Review Exercises. Volume Review Exercises, and Course Examination), consult your education officer. training officer. or NCO, as appropriate. If he can't answer your question. send it to ECI. Gunter AFB. Alabama 36114. preferably on ECI Form 17. Student Request for Assistance.

This volume is valued at 33 hours (11 points).

Contents

Page

Preface . . . . *iii*

Chapter

1 TRANSPARENT ENCLOSURES 1

2 FIBERGLASS ENCLOSURES AND PARTS 24

3 METAL BONDED HONEYCOMB 55

4 AIRCRAFT CABLE AND PLUMBING REPAIRS 74

CHAPTER 1

Transparent Enclosures

HAVE YOU ever thrown your plastic goggles in your toolbox? Have you placed tools on them? Did they become so scratched as to impair vision? If so. you now know that transparent plastics do not possess the surface hardness of glass and are more easily scratched. Since scratches impair vision, care must be exercized in handling transparent plastics to avoid damaging the surface. You will be working with plastics because they are used for domes, gun turrets, bubbles. windows, radomes. and other enclosures of military aircraft. Good visibility is of the utmost importance. The optical qualities of transparent material used in aircraft enclosures must be as good as those of the best quality plate glass. The quality must be such that personnel can locate and identify other aircraft in flight. maintain position in formation flying, sight guns accurately, and assure positive depth perception necessary to land aircraft safely at high speeds. In addition to visibility, you are concerned with strength, contour, and proper function of repaired units.

2. In this chapter you will study the properties and characteristics of transparent plastics and the various techniques. tools. and equipment used to clean, inspect, repair, and install transparent sections.

3. The maintenance and repair of aircraft plastics can be greatly simplified if you have a thorough understanding of the properties involved.

1. Transparent Plastics

1-1. The plastic industry began about 1870 when a young American, searching for a new material for billiard balls, developed a material he called celluloid. Celluloid is a mixture of cellulose nitrate and camphor which has been treated with heat and pressure.

1-2. Approximately 30 years later, or near the beginning of the 20th century, a German found that it was possible to develop a substance with plastic characteristics by mixing formaldehyde and sour milk. In 1909 a synthetic resin was developed by an American, Dr. Leo Baekeland; this substance was called bakelite. Bakelite is a mixture of phenol and formaldehyde. Much progress has been made in the field of plastics since these early discoveries.

1-3. At the beginning of the plastic industry, the outstanding characteristic of this new nonmetallic material was its ease of molding. Nearly all of the early day products were of the molded type. Today, a large percentage of plastic products are cast, machine-rolled, laminated, or formed by other methods.

2. Classes and Types

2-1. When classifying plastics according to their chemical sources, they are placed in four general groups: natural resins, protein plastics, cellulose plastics, and synthetic resin plastics.

2-2. **Natural Resins.** Natural resins include such materials as shellac, pitch, asphalt, and resin. These materials require fillers and can be molded. These plastics are not very useful in aircraft work because of their poor resistance to weathering.

2-3. **Protein Plastics.** Protein plastics are made from agricultural products. Sources include peanuts, cashews, milk, coffee beans, and soy beans. Some products manufactured of this type are plastic cups and plates.

2-4. **Cellulose Plastics.** Cellulose plastics are the oldest group and include celluloid. Other plastics which fall into this class are acetate, nitrate, ethyl cellulose, and butyrate. Cellulose is made of wood pulp and cotton linters mixed with various acids, such as nitric and acetic acids. The plastic made of the acetic acids, and known as a transparent cellulose acetate, is used for some aircraft enclosures. This type is used mostly for the smaller liason planes and older aircraft. The disadvantages for its use on aircraft are due to its poor weather resistance and its sensitivity to change of humidity. Cellulose nitrate, which is one of the toughest of all thermoplastics cannot be molded. It must be fabricated from preformed sheet, rod, or tube material.

2-5. **Synthetic Resin Plastics.** Synthetic resin plastics are the largest and most important of the group. Synthetic materials are derived from coal, air, water, urea, petroleum, ethylene, phenol, formaldehyde, etc. Products made from synthetic resins include acrylic plastic, nylon, vinyl, styrene, polyethylene, urea-formaldehyde, and others. Synthetic plastics are both of thermoplastic and thermosetting type and can be molded by the various molding processes using heat and pressure or laminated under high and low pressure. They are produced in flat sheets, rods, tubes, and many other shapes in the extruded form. These synthetic plastics may be opaque, transparent, or translucent. Transparent plastic transmits both light and sight or image, while translucent transmits light only and no image. The opaque plastics transmit no light or image.

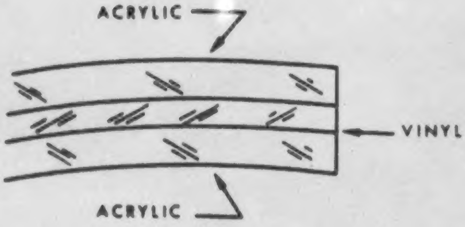
2-6. **Thermoplastic and Thermosetting Plastics.** Thermoplastic and thermosetting plastic materials require heat and pressure when formed. Thermoplastic materials may be reheated and reformed, whereas, thermosetting plastics cannot be reheated and reformed. In the manufacture or fabrication of thermosplastics no chemical change takes place, whereas filler and fiber are added to thermosetting plastics and a chemical change takes place and the materials set when formed. Once formed, thermosetting plastic products are not soluble or subject to attack by chemicals. They retain their shape until they become useless from deterioration, damage, etc.

2-7. Thermoplastic materials have characteristics similar to those of sulphur and sealing wax. Sulphur is a hard, brittle material until it is exposed to heat. It then becomes soft and pliable; it has the consistency of a liquid if enough heat is applied. After cooling, sulphur again becomes hard and brittle. However, any time it is reheated, it can be cast or molded into any desired shape without damage to the material unless the specified heat ranges are exceeded.

2-8. You work a great deal with acrylic plastics which are synthetic and thermoplastic. The major use of transparent acrylic plastic is for aircraft canopies, windows, blisters, domes, and similar transparent enclosures. Three types of transparent plastics commonly used are acrylic plastics (also known as acrylate or methacrylate base plastics), cellulose acetate base plastics, and laminated acrylic plastics. Laminated acrylic plastics are made by bonding acrylic plastic with a vinyl resin interlayer, as shown in figure 1.

2-9. Acrylic plastics are used for enclosures because of high transparent properties, strength-to-weight ratio, and forming ability.

ACRYLIC PLASTIC SHEET



ACRYLIC-VINYL LAMINATE

:3450-4-1-1

Figure 1. Types of transparent acrylic plastic enclosure

2-10. In addition to ease in fabrication and maintenance, plastics have other characteristics which make them better than glass for use in transparent enclosures. Plastics break in large dull-edged pieces; and they do not readily fatigue-crack from vibration. But on the other hand, although they are nonconductors of electricity, they become highly electrostatic when polished.

2-11. Plastics do not possess the surface hardness of glass; so they are more easily scratched. Since scratches impair vision, be careful when servicing an aircraft to avoid damaging the transparent plastic parts. Specific procedures are discussed elsewhere in this chapter; some general rules to follow are:

a. Handle transparent plastic materials only with clean cotton gloves.

b. Never use harmful liquids as cleaning agents.

c. Follow rigidly the applicable instructions for fabrication, repair, installation, and maintenance.

d. Avoid operations which might tend to scratch or distort the plastic surface. Be careful not to scratch the plastic with finger rings or other sharp objects.

3. Identification

3-1. Plastics used in transparent enclosures and combat type aircraft are generally acrylic. Cellulose acetate base plastics are used on training and observation aircraft, gliders, and helicopters. When available, acrylic plastics may be substituted for acetate base plastics; however, because of inferior strength qualities (poor resistance to weather, high degree of warpage, and poor transparency) cellulose acetate base plastics are never substituted for acrylic plastics. Therefore, use utmost care in proper identification of original, replacement, or repair materials.

3-2. Acrylic plastics are manufactured under the trade name of Lucite by the E. I. DuPoint de Nemours and Company, Inc., and Plexiglas is manufactured by the Rohm and Haas Company. Laminated acrylic plastics are made by bonding acrylic plastic with a vinyl resin interlayer but are not identified by specific trade names.

3-3. Cellulose acetate base plastics are manufactured under the trade names of Fibestos, manufactured by the Monsanto Chemical Company; Lumarith is manufactured by the Celanese Corporation of America; and Plastacele is manufactured by the E. I. DuPont de Nemours and Company, Inc.

3-4. The plastic type, military specification, and thickness in thousandths of an inch are clearly marked on the protective masking paper sheet found on both sides of the plastic sheet.

3-5. The identity of transparent plastics used on aircraft is determined by the MIL specification number on the part. If the parts are not marked, the information in the following paragraphs will help you identify the material. Common MIL numbers and the type of material are as follows:

Specification	*Type of Material*
Monolithic	
Thermosplastic:	
MIL–P–6886	Regular Acrylic
MIL–P–5425	Heat-Resistant Acrylic
MIL–P–8184	Craze-Resistant Acrylic
Thermosetting:	
MIL–P–8257	Polyester
Laminated	
MIL–P–7524	Laminated MIL–P–5425
MIL–P–25374	Laminated MIL–P–8184

3-6. Transparent plastic enclosures and plate glass enclosures can be distinguished from each other by lightly tapping the material with a small blunt instrument. Plastic will resound with a dull or soft sound; in contrast, plate glass will resound with a metallic sound or ring.

3-7. Very few of the transparent plastics are color clear when viewed from the edge. Specifications MIL–P–6886 and MIL–P–5425 are practically clear. Specification MIL–P–8184 has a slight yellowish tint. Specification MIL–P–8257 has a bluish or blue-green tint.

3-8. The cellulose acetate plastics have a yellowish tint when viewed from the edge, and they are softer than the acrylic plastics.

3-9. Both acrylic and cellulose acetate base plastics have characteristic odors, especially when heated or burned. Burning a small sample and comparing its odor to that of a known sample is a very reliable method of identification. The acrylic odor is fairly pleasant, but acetate is very repulsive. Acrylic plastic burns with a steady, clear flame. Acetate burns with a sputtering flame and dark smoke.

3-10. These plastics are also identified by the application of acetone and zinc chloride. Partially fill an eye dropper with a solution of acetone and apply it on an area of the plastic where it will not interfere with vision. Then blow on the area. If the plastic is acrylic, it will turn white; if it is acetate, it will soften but will not change color. A drop of zinc chloride placed on acetate base plastic will turn the plastic milky; but it will have no effect on acrylic plastic.

4. Storage

4-1. We have learned acrylic plastics are thermoplastic and soften and deform when heated sufficiently. To prevent the sheets from warping, they must be kept out of excessively warm storage places. Keep plastic sheets away from heating coils, radiators, hot water, and steampipes. Store them in a cool, dry location away from solvent fumes which prevail near spray and paint storage areas. Although sunlight is not harmful to plastics, keep the masked sheets out of the direct rays of the sun because sunlight may cause the masking paper adhesive to cling to the plastic and make its removal difficult.

4-2. When masking paper is difficult to remove, moisten the paper with aliphatic naphtha to loosen the adhesive. Then immediately wash the surfaces with clear water. Remember, aliphatic naphtha is highly volatile and flammable. Always exercise extreme care when using this solvent. Tools are never used in removing the masking paper because of the danger of scratching the surfaces.

4-3. After you remove masking paper from plastic sheets, check to be sure that no adhesives remain on the sheets. Use a piece of the removed masking paper to dab the areas until all adhesives are picked up. Hold the sticky side of the masking paper down as you dab.

4-4. Do not use gasoline, alcohol, kerosene, benzene, xylene, ketones (including acetone, carbon tetrachloride, fire extinguisher, or deicing fluids), lacquer thinners, aromatic hydrocarbons, ethers, glass-cleaning compounds, or other unapproved solvents on transparent plastic to remove masking paper or other foreign material; these soften or craze the plastic surface.

4-5. Leave the masking paper on the plastic sheet as long as possible. Even though this paper is tough enough to protect the plastic from minor scratches, always exercise care when sliding large sheets over each other or across tables.

4-6. Store plastic sheets (with the masking paper in place) in bins which are tilted at approximately a 10° angle from the vertical to prevent buckling. When storing vertically, place the sheets tightly so they will give support to each other. It is recommended that you store them in their original packing cases. When it is necessary to store sheets horizontally, take care to avoid getting chips and dirt between the sheets. Stack the sheets on top of each other, in stacks no higher than 18 inches. Always place the smaller sheets on the larger ones to avoid unsupported overhang, as shown in figure 2.

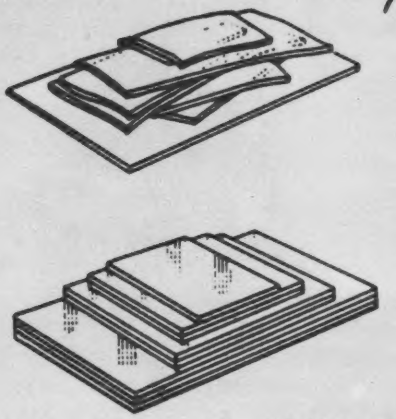
4-7. If sheets become bowed as a result of improper storage, straighten them by removing the masking paper, heating to forming temperature, placing them on a flat flannel-covered surface, and then allowing them to cool.

4-8. Store formed sections so they are amply supported and so there is no tendency for them to lose their shape. Simple frames or supports are often desirable to relieve strain or unusual pressure on curved parts. Keep formed parts covered with cloth or soft paper to protect them from dust. Also protect formed sections against temperatures higher than 120° Fahrenheit. Such temperatures cause them to lose their shape.

4-9. When you find it necessary to remove masking paper from the plastic sheet during fabrication, remask the surface as soon as possible. You can replace the original paper on relatively flat parts or apply a protective coating on curved parts.

4-10. Certain protective coatings are available for formed parts. The coatings are applied by spraying. The minimum allowable thickness of the coating is 0.0009 inch. A layer of cheesecloth is embedded in the coating at the time of application to assist in removal of the masking spray. Coatings which remain on formed parts longer than 12 to 18 months become difficult to remove. Do not store transparent plastics or formed parts coated with this material outdoors where they will be subject to direct sun for longer than 4 months.

4-11. To remove spray masking from the plastic, peel it off. If the film is too thin to remove in a continuous film, apply a fresh coating of the compound, reinforced with a layer of cheesecloth, to obtain a thicker film and allow to dry. Soaking the coated part with clean cloths saturated with water at room temperature softens the film. You can then peel it off by hand. Do not use a solvent. Exercise care to avoid scratching the surface of the plastic. Do not use tools to remove the film because of the danger of scratching the plastic. Storage of transparent plastic sheets presents no special fire hazard, as they are slow burning.



53450—4—1—2

Figure 2. Horizontal storage.

5. Cleaning

5-1. The steps that you will follow in cleaning plastic enclosures should become a permanent part of your procedure.

a. Always remove rings from your hands.

b. Rinse the plastic surface with plenty of water, using your bare hands to feel for and gently dislodge any dirt, sand, or mud.

c. Wash with mild soap and water. Be sure the water is free of harmful abrasives. Use a soft cloth, sponge, or chamois while washing but only to carry the soapy water to the plastic. Go over the surface with your bare hands to quickly detect and remove any remaining dirt before it scratches the plastic.

d. Dry with a damp clean chamois, a clean soft cloth, or soft tissue. Do not continue rubbing the transparent plastic after it is dry.

e. Clean with an approved cleaner for transparent plastics. If none of the approved cleaners is available, after soaping, rinse thoroughly with clear water (distilled water if possible) in a shaded area. Cleaning with water in the sunshine causes water spotting, which is objectionable to the pilot's vision.

f. Do not rub the plastic with a dry cloth. This not only causes scratches but builds up an electrostatic charge which attracts dust particles. If the surface becomes charged, pat or gently blot with a clean damp chamois to remove the charge as well as the dust.

g. Clean with an approved cleaner (Specification MIL–C–18767). Never use a coarse or rough cloth for polishing. Cheesecloth is not acceptable.

5-2. The procedure for cleaning interior surfaces consists of three steps:

(1) Dust the plastic surface lightly with a clean, soft cloth saturated with clean water. Never use a dry cloth.

(2) Wipe carefully with a damp, soft cloth or sponge. Keep the cloth or sponge free from grit by rinsing it frequently with clean water.

(3) Clean with an approved cleaner.

5-3. Routine removal of traffic film and other operational soils (where abrasive polishing for scratch removal is not required) is done by the use of aqueous detergent solutions. The following materials are recommended: Wetting Agent, Synthetic, Nomionic, Specification MIL–D–16791; or Agent, Wetting, Alkyl Aryl Sulfonate, 40-percent active. Use these materials in concentrations of 2 to 3 ounces per gallon of water. Apply with soft cloths or photographic cellulose sponges which have been used for no other purpose. Polish and cleaner Specification MIL–C–18767 gives satisfactory results for most cleaning requirements.

5-4. After the surface has been cleaned and no scratches are present, apply one or two coatings of an automobile or furniture wax to produce a surface gloss. Such a waxy glass aids in protecting the plastic from abrasions.

6. Inspection

6-1. Your inspection of plastics requires checking for scratches, nicks (chipping), cracks, bubbles, delaminations, fractures, crazing, and optical distortion. You visually inspect to determine if the assembly meets surface and optical requirements as outlined in the applicable technical order. The acceptable imperfection limits are given for windshields, side panels, canopies, etc. After reworking the assemblies or parts, inspect them for optical distortion, for thickness of glass, and for compliance with the applicable technical order. You must also exercise good judgment when you inspect.

6-2. Scratches are the most common defects in plastics. The length, depth, number of them in a given area, and location determine whether to replace the enclosure or plastic panel. Scratches are acceptable if they can be sanded or buffed out without reducing the panel thickness to less than prescribed by the applicable technical order without impairing vision. Nicks (chipping) are similar to scratches; these may be removed by sanding. However, this is not done if the removal of the material reduces the panel thickness to less than prescribed by the applicable technical order, or if the removal impairs vision.

6-3. Cracks and fractures are not acceptable in plastic enclosures. However, a temporary repair for a crack is given in TO–1–1A–12, *Fabrication, Maintenance, and Repair of Transparent Plastics*. Use this repair only under extreme emergency conditions.

6-4. Surface imperfections (orange peel, pits, pimples, and mark-off) caused by lint impression are acceptable, provided these conditions do not impair vision or cause localized distortion.

6-5. Bubbles are found mostly in laminated plastics. They are acceptable if well scattered, provided they do not impair vision. The applicable technical order gives you the acceptable number, diameter, and spacing for each area on the enclosures, panels, and windows.

6-6. Delaminations are found in glass and laminated plastics. This is a separation of the outer or inner face ply and the vinyl core. The strength of the window is not seriously affected by delamination, but visibility can be reduced and window heating impaired because of damaged conductive coating. When either visibility or window heating is impaired, the delaminated window is replaced (glass laminate construction will be discussed later in this chapter). Delaminated windows are sometimes confused with chipped windows, which are a cause for immediate removal. To avoid confusion, you can identify a delaminated window by the following characteristics of the material:

a. The delaminated area is smooth in appearance in both direct and indirect light.

b. Visual distortion through the delaminated area is slight except along the edges of the delaminated area.

c. Delamination generally begins near the edge of the glass and spreads inward toward the center and along the edge.

d. Unless viewed at an angle, the delaminated area may be difficult to detect.

e. A milky (cloudy) appearance anywhere around the edge of either the inner or outer glass is an indication of actual or imminent delamination as a result of moisture penetration.

f. Large bubbles between layers or plies of glass.

6-7. Chips on the laminated surface of the glass are layers or flakes of glass broken from the surface by excessive stresses in areas where the strength of the bond between the core and the glass is greater than the surface strength of the glass. Chipping seriously weakens the glass pane in which it occurs and may damage the conductive coating. Any window in which the inner pane is chipped or window heating is impaired is replaced. A chipped window is identified as follows:

a. A chipped area has a rough or grained appearance which is readily detectable in reflected light.

b. White powdered glass is often seen in a chipped area.

c. Visibility through the chipped area is poor and badly distorted.

d. A chip may occur anywhere on the inner surface of a windowpane. It usually starts at a small point of origin and progresses outward from this point. Again check the applicable technical order for the acceptable number of separations, length, and width of each chip.

6-8. Earlier you were told about plastics crazing, but we did not give you a description. We told you many types of chemicals would cause plastic to craze. Now you must know how it looks, what causes it, and how to prevent it. If you will, take a piece of cardboard and bend it until you have an angle of 90° or more. Looking at the outside angle, you will see many little cracks in the radius of bend. It also resembles the cracking on pottery or surface splits on weathered wood. You also know that metal cracks in areas of high localized stress. Under similar conditions, acrylic plastics develop small surface fissures called crazing. Figure 3 indicates how crazing appears in plastics. These tiny cracks are difficult to detect, since they are approximately perpendicular to the surface, very narrow, and usually not over 0.01 inch in depth. They can be best seen by moving the piece to be inspected under an overhanging light and looking at the surface of the plastic in front of a dark background. You can do this on an aircraft by using a light (flashlight or extension light) while looking on the outside surface and having a dark surface (cardboard or other black paper) on the underside. The minute fissures are both an optical and a mechanical defect because there is a separation of material. The edges of crazing fissures cause undesirable highlights and reflections during night flying or during daylight flights, especially when flying directly into the sun.

6-9. If the crazing is in a random pattern, it can usually be ascribed to the action of solvents or solvent vapors. If the crazing is approximately parallel, the usual cause is a directional stress set up by cold-forming, excessive loading, improper installation, improper machining, or a combination of these.

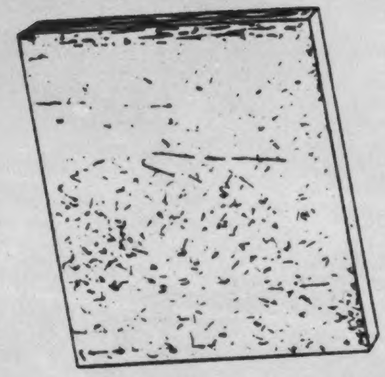


Figure 3. Crazing.

6-10. Once a part has crazed, neither the optical nor the mechanical defect can be removed. Consequently, the preventive measures are as follows:

a. Forming at sufficiently high temperature.

b. Proper control of sawing, drilling, milling, routing, sanding, polishing, and other machining operations.

c. Care in application of an approved cement.

d. Careful installation in an approved manner.

e. Use of approved cleaners only.

f. Keeping acrylic parts away from solvents or solvent forms.

g. Proper annealing of fabricated parts is the most effective single preventive measure against crazing.

6-11. Scattered areas of light crazing are allowable in the canopy glass, windows, and other enclosures. They must be within the established optical requirements for the individual aircraft and never in an area that would impair vision.

6-12. In the process of checking the windshield or glass enclosures for distortion, etc., you will find it very difficult to define all the structural defects that are possible. Use good judgment when deciding the structural significance of these defects.

6-13. One way to visually examine a windshield or plastic enclosure for distortion is:

a. Place a small white light approximately 100 yards in front of the windshield.

b. Sit in the pilot's seat, in the cockpit, and look at the light.

c. Similate motions of pilot's head.

d. Any distortions observed 1 inch or closer to the windshield frame is considered normal.

e. If you see distortions that affect safety of flight, the windshield or plastic enclosure must be replaced.

6-14. Earlier we mentioned that under certain conditions, scratches in panels are acceptable. The applicable technical order contains the minimum acceptable thickness of panels after the scratch has been worked out. Before you work the scratch out of the panel, determine how thick the panel should be after you complete the work. If the panel thickness is less than the limit given in the applicable technical order, the panel must be replaced rather than repaired. To anticipate the thickness of the panel after the scratch is removed, use the optical micrometer before you remove the scratch. Here is what you need to know to use the optical micrometer when you measure the thickness of the panel:

a. Place a grease pencil mark on the far side of the panel and focus the micrometer on the mark. Read and record the setting on the micrometer.

b. Place a grease pencil mark on the near side of the panel and focus the micrometer on the mark. Read and record the setting on the micrometer.

c. Subtract the second reading from the first reading and multiply this difference by the constant 1.5 to get the thickness of the panel.

d. To measure the thickness of the glass at the scratch before you rework it, use the bottom of the scratch as the focal point (instead of the grease pencil mark on the one side). Look at the illustration in figure 4, then follow the procedures above.

7. Maintenance of Acrylic Plastics

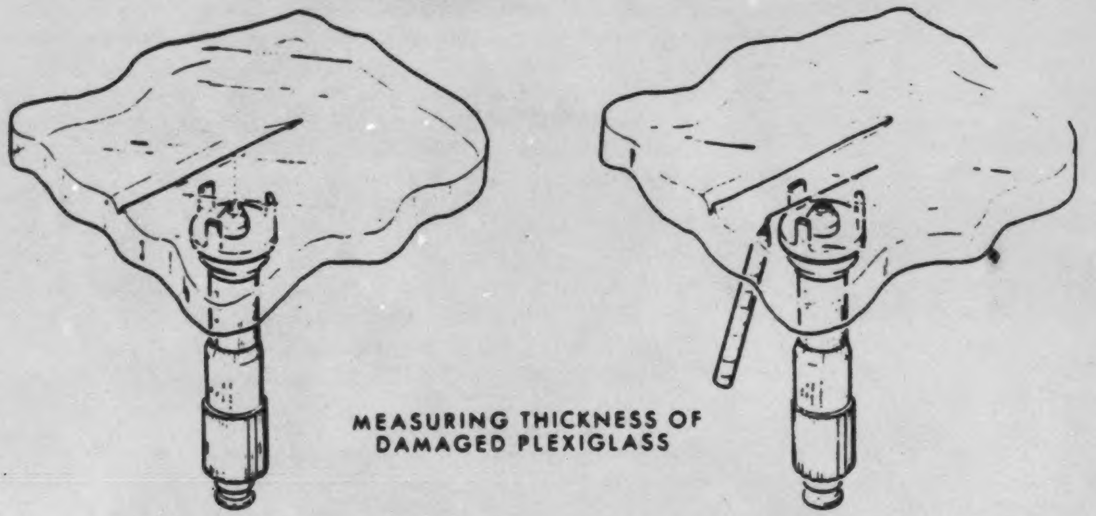
7-1. To properly maintain crew enclosures, keep them clean and free of damage. Fabrication, repair, and maintenance procedures differ with plastic used and the function of the aircraft. Procedures set forth in this chapter apply chiefly to acrylic plastics and consist of those processes which can be accomplished in the shortest possible time with the simplest equipment. The temporary repair procedures given here are recommended for use *only* under emergency conditions. Any damaged plastic part should be replaced. In some cases, the part may be patched temporarily and then replaced as soon as possible. Even a perfectly patched part is neither optically nor structurally equal to the new section.

7-2. **Machining.** The fabrication properties of acrylic plastics are generally compared to those of wood or soft metal. Good craftmanship, suitable equipment, and proper design are just as necessary to successful fabrication of acrylic parts as they are to good workmanship in wood. Light to medium woodworking equipment produces satisfactory results; however, heavy-duty machines, which are less apt to vibrate, are even better. General rules of machining apply; and once you get the "feel" of the plastic, you can do clean, accurate work. Keep your tools sharp and free from nicks and burrs. Since these plastics soften or become gummy when they are hot, keep frictional heat from building up or dissipate the heat by the application of a lubricant. Water or a mild soap solution makes a good lubricant for acrylic plastics and, if applied to a drill or saw, prevents burning and clogging. If the masking paper is still intact, be careful that contact of the lubricant with the masking paper is kept to a minimum. Moisture will cause a loss of strength in the masking paper, and removal is difficult. To prevent scratching during machining and forming operations, keep plastics covered either by applying masking tape or by leaving in tact the masking paper applied by the manufacturer.

7-3. **Cutting.** Where extreme accuracy is not required, laying out the work may be accomplished by penciling and cutting lines directly on the masking paper. For close tolerances, however, it is advisable to scribe layout lines directly on the surface of the plastic. Use straightedges or layout templates according to the requirements of the job. If the masking paper is removed before scribing replace it again to within about 1/4 inch of the scribed markings before the piece is cut.

7-4. Layout templates may be of plastic sheeting to which suitable handles can be cemented. Round the sharp edges and smooth the rough spots. In the case of metal templates, it is good practice to cement thin flannel over the contact surfaces.

7-5. To cut plastic sheets, use ordinary hand, hack, band, circular, or jigsaws. Thin sheets may be cut by scribing a deep line, then breaking along the line. Hand and hack saw teeth should have very little set and should be fine enough so that at least two teeth are cutting at all times. To cut 1/8-inch stock, for example, you use a saw blade having a minimum of 16 teeth per inch. Band saws dissipate heat more readily then do circular saws. Accordingly, they operate at lower temperatures and are better suited for cutting thick plastic sheets. Fine teeth with no *set* produce a smooth cut if the work is fed slowly. If curves are to be cut, *set* is necessary even though narrow blades are used. Use jig saws for cutting curves with small radii and band saws for larger curves. Adjust the blade guides as close to the work as possible so that control "weave" is kept



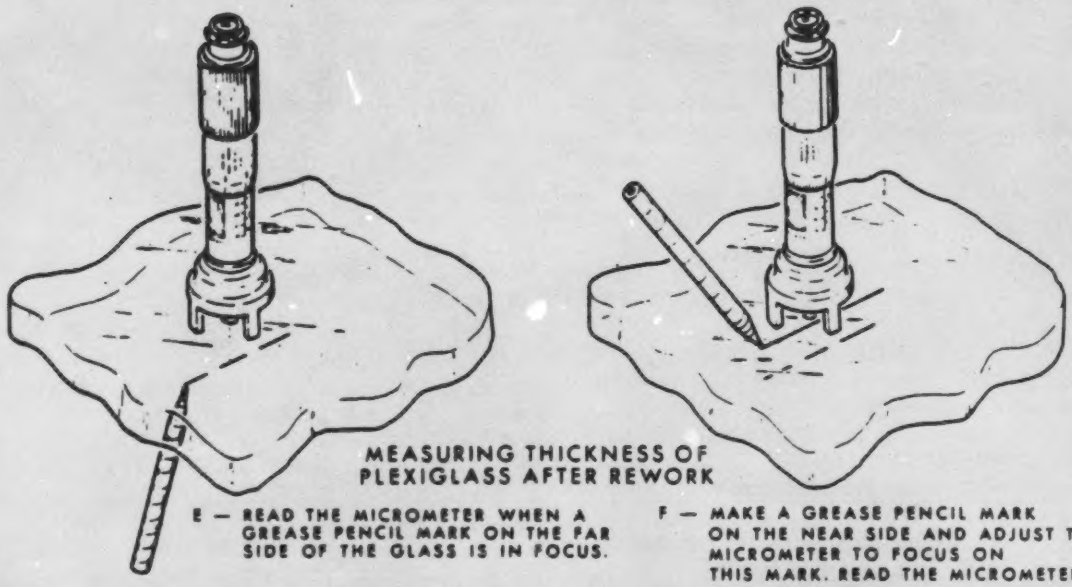
MEASURING THICKNESS OF DAMAGED PLEXIGLASS

A — FOCUS ON THE APEX OF A SCRATCH FROM THE FAR SIDE OF THE GLASS. READ THE MICROMETER.

B — MAKE GREASE PENCIL MARK ON THE NEAR SIDE AND ADJUST THE MICROMETER TO FOCUS ON THIS MARK. READ THE MICROMETER.

C — SUBTRACT READING "B" FROM READING "A".

D — MULTIPLY THIS DIFFERENCE BY THE CONSTANT 1.5 TO GET THE THICKNESS OF THE GLASS THAT WILL REMAIN AFTER SANDING OUT THE SCRATCH.



MEASURING THICKNESS OF PLEXIGLASS AFTER REWORK

E — READ THE MICROMETER WHEN A GREASE PENCIL MARK ON THE FAR SIDE OF THE GLASS IS IN FOCUS.

F — MAKE A GREASE PENCIL MARK ON THE NEAR SIDE AND ADJUST THE MICROMETER TO FOCUS ON THIS MARK. READ THE MICROMETER.

G — SUBTRACT READING "F" FROM READING "E".

H — MULTIPLY THIS DIFFERENCE BY THE CONSTANT 1.5 TO GET THE THICKNESS OF THE GLASS.

53450—4—1—4

Figure 4. Measuring thickness of plexiglass assemblies.

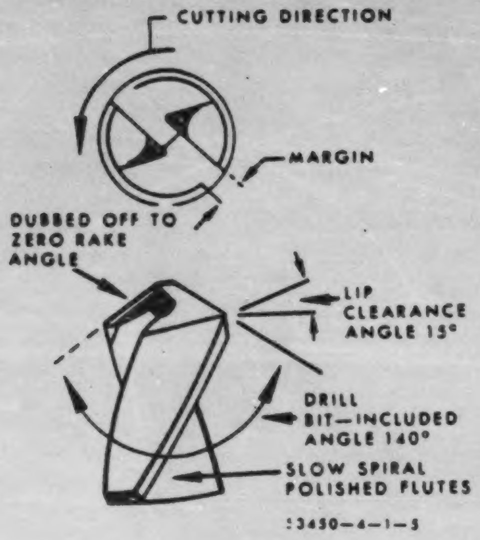

CUTTING DIRECTION
MARGIN
DUBBED OFF TO ZERO RAKE ANGLE
LIP CLEARANCE ANGLE 15°
DRILL BIT—INCLUDED ANGLE 140°
SLOW SPIRAL POLISHED FLUTES
53430-4-1-5

Figure 5. Recommended drill for plastics.

to a minimum. Metal cutting blades have been found best for cutting plastics.

7-6. The feed for all types of hand and power saws. cannot be accurately stated—it must be learned from experience—but in general, it is relatively slow. Moderate smoking and smearing at the edges are indications of too rapid a feed or too much pressure.

7-7. **Drilling.** To drill holes use an end mill or an ordinary twist drill with the point ground. as shown in figure 5. Use a moderate drill speed. feed slowly, and use light pressure to avoid "grabbing." especially as the drill breaks through on the other side of the piece of plastic. During the drilling operation, hold the work securely by clamps or other fixtures provided. Portable hand drills may be used in conjunction with special jigs; however, drill presses produce better drilling results.

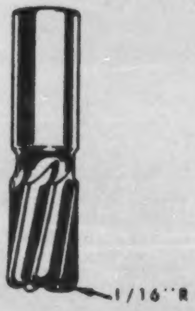
7-8. As in the case of sawing, the feeding rate is a matter of experiment and judgment. Too fast a feed will cause chipping and strain cracks. Proper feed is indicated by smooth, continuous spiral chips or ribbons. Avoid overheating by decreasing the rate of feed as the depth of cut is increased.

7-9. Use drill lubricants because they aid in chip removal. dissipate heat. and improve the surface finish of the hole. The best lubricant for drilling acrylics is a thin mild soap solution. It is possible to drill shallow holes satisfactorily without the use of a lubricant if you feed the stock slowly to avoid overheating. Lifting the drill from the work frequently to let it air-cool is good practice.

7-10. **Smoothing and Routing.** Ordinary rasps and files are used satisfactorily for smoothing and beveling the edges of plastic sheets. Plastics are sanded by hand or buffed (explained in a later paragraph). They are planed, routed, or jointed on high-speed woodworking machines. The primary tool you will use in routing plastics is a pneumatically powered, hand-operated router with speeds ranging from 10,000 to 20,000 rpm (revolutions per minute). The router is used with the support assembly, bit, and template. The support assembly threads onto the router body. You adjust it to the desired depth of cut with its (clamping nut) mechanism, which holds the depth adjustment in place. One complete turn of the support adjustment changes the depth of cut approximately 0.083 inch. Metal cutting ¼-inch right-hand spiral mill bits are used with the router during removal of the damaged areas in plastic. The router bits must be kept sharp, clean, and protected against nicks, breakouts, or other damage. When routing, keep the corner of the cutter slightly rounded so that a radius of at least 1/16 inch is left in the corners, as shown in figure 6. A rounded routing edge reduces the possibilities of eventual cracking. Of the several high-speed portable routers, the standard two-blade woodcutters give satisfactory results. On vertical spindle shapers, multi-blade cutters of two, three, or even more blades may be used. In general, the greater the speed the less the number of cutting edges required Cutters up to 3 inches in diameter may be used without difficulty.

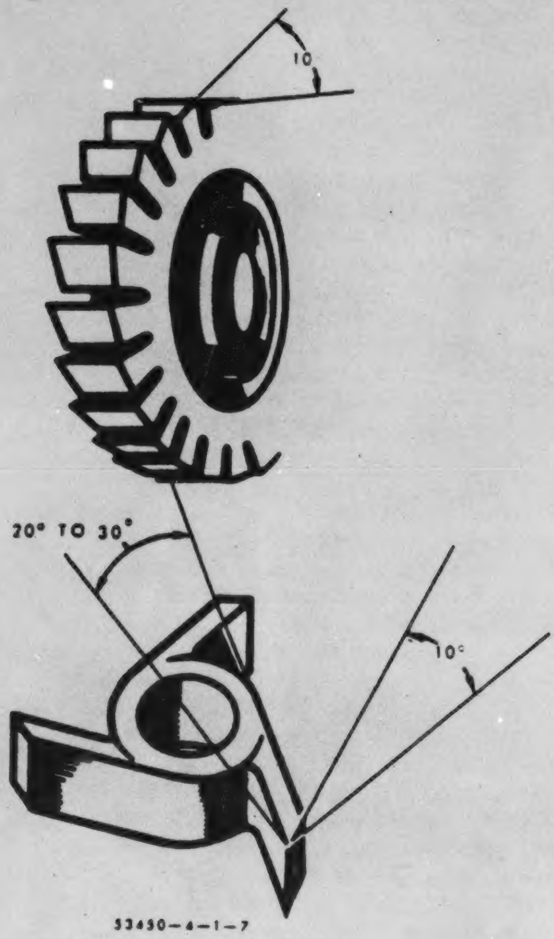
7-11. Keep the cutters sharp. Always grind cutters with a back clearance of about 10°. For best results. select a cutter with 20° to 30° rake angle, as indicated in fugure 7.

7-12. For rabbet or stepped routs (shown in fig. 8) hack off the underside of the teeth of the cutter in order to prevent drag and thus avoid burning the plastic. Whenever possible, grind the



THE ROUTER BIT SHOULD BE ROUNDED TO A RADIUS OF 1/16 INCH TO MAKE A ROUNDED ROUTING EDGE.

Figure 6. Router bit.



53450—4—1—7

Figure 7. Router cutter.

corners of the routing cutter to a 1/16-inch radius to produce a fillet at the bottom of the rout. Where the router spindle collar bears on the edge of the plastic during routing procedures, use a ball bearing collar (or oil the collar or edge) to reduce friction and excess heating. It may be impossible to hold close tolerances in both the depth of the cut and the toe of the rout unless a subsequent compensating machine routing is carried out after routing.

7-13. Use cutters ground to the desired shape when routing special cross sections. Rib shapes, for example, can be made by routing strips in much the same way as wood molding is produced.

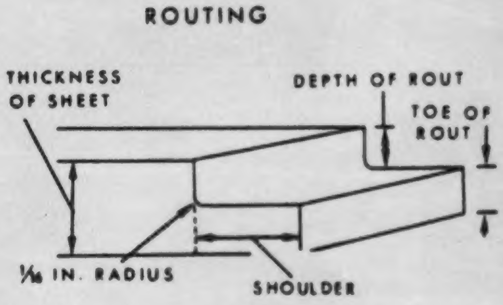
7-14. Standard metalworking lathes may be used in turning transparent plastics. Heavy wood lathes may be used, but they are usually less satisfactory.

7-15. **Forming.** Transparent plastics become soft and pliable when heated to their respective forming temperatures. They can then be formed to almost any shape; and, on cooling, the material retains the shape to which it was formed, except for a small contraction. It it not desirable to cold-form compound curvature transparent plastics that is, to spring them into a curved frame without heating.

7-16. Transparent plastics may be cold-bent (single curvature) if the material is thin and the radius of curvature to which it is cold-bent is at least 180 times the thickness of the sheet. For example, an 18-inch length of transparent plastic 0.250-inch thick should not be deflected more than ¾ inch. Cold-bending beyond these limits may eventually result in tiny fissures (crazing) appearing on the surface of the plastic because of stresses being imposed beyond those recommended for continuous loading. For hot-forming, transparent plastics should be maintained at the proper temperature as recommended in TO 1-1A-12, *Fabrication, Maintenance, Repair of Transparent Plastics.*

7-17. Use an oven for softening transparent plastic sheets prior to forming. A circulating air oven is preferable. A fan or other means of forced circulation is employed to maintain even heat through the oven. The oven must be capable of operating over a range of 49° to 190° centigrade (120° to 374° F.). For uniform heating, it is best for you to hang the sheets of plastic vertically, using an overhead monorail mounted in the roof of the oven and equipped with a spring channel or a series of clips for grappling the plastic sheet, as shown in figure 9.

7-18. For small pieces which are inconvenient to handle and for pieces cut with insufficient trim to which the clips or channels can be clamped, shelves or drawers must be provided. Shelves covered with soft felt or flannel are of openwork construction to assure maximum circulation or air around the sheet for uniform heating.



53450—4—1—8

Figure 8. Step rout or rabbet.

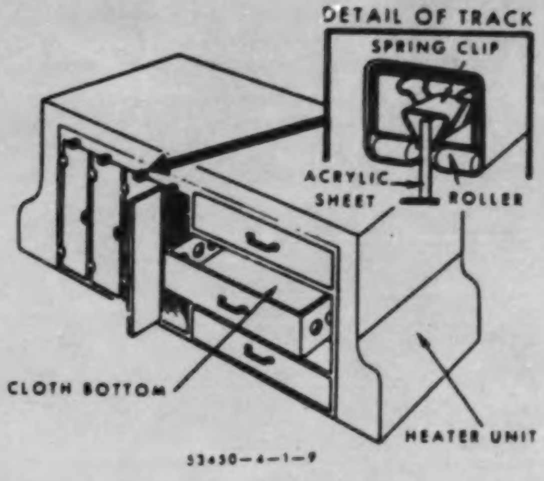


Figure 9. Forming oven.

7-19. Be sure the air distribution is uniform over the entire surface. Such an arrangement necessitates filtration of any fresh air which is admitted to the oven. In an emergency, any available oven (such as a kitchen baking oven) may be used. Wear white cotton gloves while handling the unmasked sheeting. Ovens are used also for annealing plastic enclosures before and after cementing and after matching or fabrication.

7-20. Sometimes other means are employed for heating transparent plastic prior to forming. For example, infrared lamps may be used. They are usually arranged on 7- to 8-inch centers in a bank sufficiently large to cover the maximum size sheet involved. The sheeting should be placed approximately 18 inches from the face of the lamps to obtain even distribution of the radiant heat. In general, any method other than oven heating is undesirable and should be used only in emergencies.

7-21. Do not use hot water or direct steam to heat transparent plastic because it may cause the plastic to become milky or cloudy.

7-22. Allow sufficient time for the entire sheet to heat to the forming temperature. Prior to heating, remove all masking paper and adhesive from the plastic sheet. If the plastic sheets are dusty or dirty, wash and rinse them well with clear water. Dry the sheets thoroughly by blotting with soft absorbent paper. Thin material must be heated to a higher temperature than thick material because it cools more rapidly.

7-23. Heating the plastic above the temperature range for the given grade of acrylic type plastic will cause bubbling on the surface of modified plastic material (Specification MIL-P-8184). In addition, overheating may impair some of the physical properties of the material before buddling is apparent.

7-24. When handling hot transparent plastic sheets, be careful to avoid fingermarking or otherwise damaging the soft surface. The transparent plastic blanks should be slightly larger than the required finished size to provide an edge which can be handled freely without danger of scarring the surface of the material of the finished part. After the material has been formed, allow it to cool slowly. Cooling should be uniform over the entire surface to reduce internal stress.

7-25. Forming temperatures and heating cycles for plastic which conform to Specification MIL-P-8257 must be in accordance with the manufacturer's instructions furnished with the material.

7-26. Since most forms used for forming transparent plastics are not subjected to great pressure, they may be made of material as brittle as plaster. For simple two-dimensional shapes, forms are easily made from metal, pressed wood or plywood. For more complicated shapes, reinforced plaster or plastic forms are easier to make and are perfectly satisfactory.

7-27. Forms should be free of waviness and other variations in contour which might cause optical distortion in the formed part. The form's surface should be sanded smooth and covered with soft cloth such as billiard felt, outing flannel, flannelette, imitation chamois, or flocked or suede rubber sheeting.

7-28. If the final dimensions of the formed parts are critical, the molds must be made sufficiently oversize to allow for shrinkage of the parts when they cool from the forming temperature to room temperature. Mold surfaces should extend beyond the trim line. The form should have some means for holding the edges of the transparent plastic sheet against the form during cooling.

7-29. It is often possible for you to make forms from plaster, using the broken panel itself as a mold in which to cast the plaster. Tape the broken panel together securely and grease the inside surface well with vaseline or soap. Pack sand around the outside surface to give adequate support while you pour the plaster and until it sets.

7-30. Several methods are used to form transparent plastics. We mentioned the simple two-dimensional shapes are those that are more complicated. First we will tell you about two-dimensional (drape) forming. Remove all masking paper from the plastic sheet before heating for forming. Rinse well with clean water. Dry the sheet thoroughly before heating. Wear soft cotton gloves and remove the hot plastic sheet

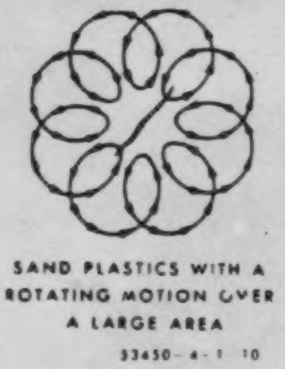


Figure 10. Sanding plastics with a rotating motion over a large area.

from the oven, laying it carefully over the form. The edges of the sheet should be held against the form, either by hand or by holddown rings or yokes, until the sheet has thoroughly cooled. Cooling may require 10 minutes to ½ hour, depending on room temperature and the thickness of the sheet. Do not force cooling.

7-31. Three-dimensional forming. Parts with compound curves can be formed from a transparent plastic sheet by any of these six different methods or occasionally by some combination of these methods:

a. Stretch forming can be done manually or mechanically. Many compound shapes can be formed by stretching the heated plastic sheet plastic sheet across a form.

b. Male and female forming can be used for compound shapes of irregular contour, such as those with reeding, fluting, steps and the like.

c. Air pressure differential without form, or free-blown method (also known as vacuum forming), is the method most commonly used for aircraft canopies. The use of air pressure differentials eliminates the objections to other methods of forming parts with compound curves.

d. Air pressure differential with female form is used when the desired part varies quite radically from a true surface tension shape by having sharp changes of contour. The part is formed by drawing it onto a female form made of plaster or metal.

e. Air pressure differential male form, or snapback method, is another method of obtaining shapes which vary from the true surface tension shape. It is based on the tendency of the heated plastic to return to its original flat sheet form, a tendency known as elastic memory.

f. Rotoforming is a term applied to a method of forming transparent plastic canopies with centrifugal force.

7-32. **Sanding.** Because transparent plastic is relatively soft in comparison to glass, and because it softens under the influence of heat, any sanding or buffing done to remove a surface blemish may result in an ultimate finish of poorer optical quality than that of untouched sheeting. Therefore, it is important that transparent plastics be handled carefully during fabrication and servicing to avoid unnecessary finishing operations. The original luster and transparency of transparent plastics is always protected with masking material, Specification MIL-C-6799. Sanding and polishing will not restore this original luster.

7-33. Never sand or buff astrodomes, sighting panels, or other critical optical parts. These parts are to be washed with soap and clear water. Parts that scratch or craze in excess of that specified as permissible in the applicable aircraft handbook are rejected.

7-34. When sanding is required, first use the finest abrasive paper that will remove the scratch or other defect (no coarser than number 320A). Wrap this paper around a felt or felt-covered wooden block and rub the defective area lightly, using water or 2-percent soap solution as a lubricant. Light pressure should be used and the strokes should be circular as in figure 10. Follow the initial sanding by similar treatments, using successively finer grades of abrasive paper grits (sandpaper) in the following sequence: 360A, 400A, 500A, and 600A. Wash the plastic after each sanding operation. During each step, remove the deeper scratches left by the preceding grade of abrasive.

7-35. Do not sand transparent plastics unless it is absolutely necessary. You may leave hairline scratches of 0.001-inch maximum depth, providing optical requirements are maintained.

7-36. The same general procedures used in hand sanding apply to sanding with power-driven sanding machines. Use extremely light pressure.

7-37. Power sanders should not be used except where the severity of the defect is such as to require excessive hand sanding. Only flat surfaces or surfaces with a radius of curvature greater than 36 inches should be power sanded.

7-38. **Ashing.** A very popular substitute for sanding is ashing. Ashing involves the use of a thick, abrasive paste (such as jeweler's rouge) applied to a cloth wheel. In this operation, speed and pressure are critical factors, so be sure to hold both these factors within safe limits to prevent overheating. Also keep either the plastic or the wheel in constant motion with relation to the other so that frictional heat will be distributed over a large area. Overheating results in a poor finish and, in extreme cases, causes formation of drag marks on the surface. Wheel speed for ashing should be about 900 surface feet per minute.

7-39. **Finishing.** Acrylic plastic is manufactured with a highly polished perfectly transparent surface. It must be kept in this highly polished condition to give good service. However, since plastic is relatively soft, as compared to glass, and becomes flexible under the influence of heat, sanding and buffing operations during the removal of a blemish must be done carefully so that the optical quality is not destroyed. Again, let us repeat, never sand or buff astrodomes, sighting panels, or other critical optical parts. Always replace such sections if they are scratched. Never sand if ordinary buffing will remove a blemish. Furthermore, do not start sanding unless you are sure that some type of power-driven buffing equipment is available or can be improvised. Hand polishing is not as effective as power buffing to restore a polish to a sanded surface.

7-40. After sanding operations are completed and before buffing is started, wash the plastic surfaces with water to avoid transfer of coarse abrasive to the buffing wheel or the hand polishing cloth. When hand polishing, use a soft damp cloth (such as soft diaper cloth, imitation chamois, glove lining, or outing flannel or flannelette) to which a suitable cleaner has been applied. Rubbing too hard or too long in the same spot causes heat to build up and soften the plastic; this must be avoided. Several applications of the cleaner may be necessary before the spot is completely cleaned.

7-41. Use a soft open type cotton, flannel, or felt buffing wheel (illustrated in fig. 11) rotating at approximately 2000 surface feet per minute for machine buffing. Hold the material (or the wheel) so that the side of the wheel being used is moving away from the operator. First, apply a light coat of tallow to the edge of the buffing wheel, then apply a good coating of buffing compound over the tallow. Hold the plastic sheet lightly against the buffing wheel and keep the sheet in constant motion to prevent burning. A straight backward and forward or side to side motion is recommended. Buff only the area from which scratches are being removed. After all sandpaper scratches have been removed, repeat the operation, using a tallow or wax buffing wheel. This time the buffing wheel should rotate at approximately 3000 surface feet per minute. Then remove all traces of tallow or wax with a clean buffing wheel, rotating at 5500 to 6500 surface feet per minute. For the final polish, apply a thin coat of good wax with a small soft cloth pad and rub the surface lightly with a piece of clean soft cloth.

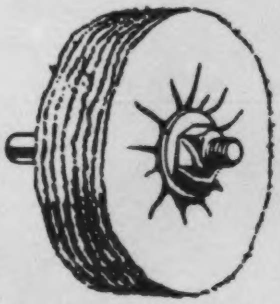


Figure 11.

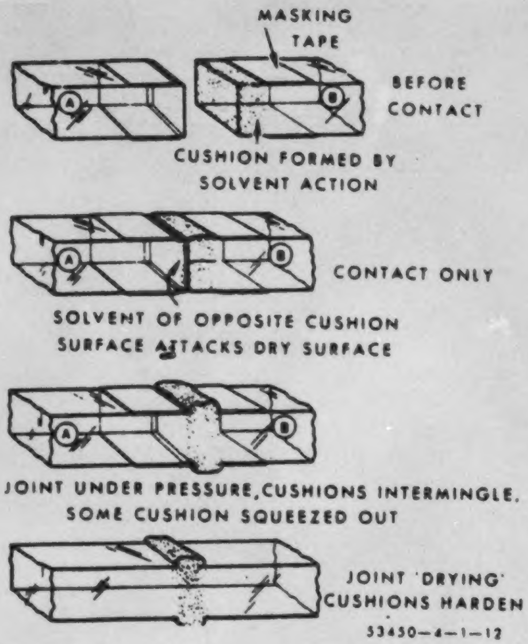

MASKING
TAPE
BEFORE
CONTACT
A
B
CUSHION FORMED BY
SOLVENT ACTION
CONTACT ONLY
SOLVENT OF OPPOSITE CUSHION
SURFACE ATTACKS DRY SURFACE
JOINT UNDER PRESSURE,CUSHIONS INTERMINGLE,
SOME CUSHION SQUEEZED OUT
JOINT 'DRYING'
CUSHIONS HARDEN
53450—4—1—12

Figure 12. Cementing with solvent cement.

7-42. **Cementing.** With care and proper procedure, it is possible to obtain a cemented joint which approximates the original plastic in strength. Cementing of transparent acrylic plastics depends on the intermingling of the two surfaces of the joint so that actual cohesion exists. To effect cohesion, an organic liquid solvent is used to attack the plastic, forming a well-defined soft surface layer called a cushion, as shown in figure 12.

7-43. The most common method of cementing transparent plastics is the "soak method." This consists of dipping one of the two pieces to be cemented into the cement until a sufficient cushion is formed. When this surface is pressed against the opposite dry surface, the excess ce-

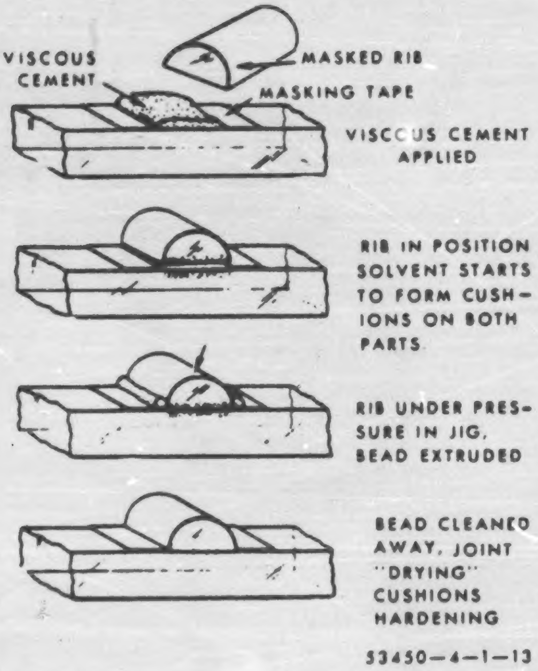

VISCOUS CEMENT
MASKED RIB
MASKING TAPE
VISCOUS CEMENT APPLIED
RIB IN POSITION SOLVENT STARTS TO FORM CUSHIONS ON BOTH PARTS
RIB UNDER PRESSURE IN JIG, BEAD EXTRUDED
BEAD CLEANED AWAY, JOINT "DRYING" CUSHIONS HARDENING
53450—4—1—13

Figure 13. Cementing with syrup cement.

ment forms a second cushion—shallow, but enough to permit thorough intermingling of the two surfaces, as shown in figure 12.

7-44. Sometimes, for convenience in handling, clear transparent plastic shavings of the same type as the transparent plastic being cemented are dissolved in the cement to give it a thick, syrupy consistency so that it can be applied like glue. This viscous cement, however, works on exactly the same principle as a soak cement; for example, the excess solvent softens and swells both surfaces, permits an intermingling of the cushions and forms a cohesive bond, as illustrated in figure 13.

7-45. For a satisfactory joint, the two pieces to be cemented should fit accurately. It is always preferable to cement flat surfaces rather than curved. It is, therefore, advisable to rout or sand curved sections to present flat surfaces before cementing. Where two curved surfaces must be cemented, as in an overlap joint of two curved sections, the curves of both should have the same radius. All cemented joints should be firmly bonded over at least 90 percent of the joint surfaces within any 2-inch length of any joint. The remaining 10 percent may have bubbles or dry spots, unless otherwise noted on applicable drawings. The two surfaces should have a fairly smooth finish. It is not necessary that they be polished, but the surfaces should be at least sanded smooth.

7-46. To confine the softening action of the cement to the area of the joint, it is necessary to mask the surrounding plastic. For this purpose, use a pressure-sensitive tape that is impervious to the action of the cement. It is important that the tape be properly applied, particularly at the edge, and that enough overlap (approximately ¼ inch) be allowed so that the cement does not seep under the edge and attack the plastic to be protected. Be sure that the edges are firmly attached and that there are no air bubbles beneath the tape. Since the application of successive strips of tape is often time consuming, it is sometimes preferable to mask a complicated or curbed part by coating it with a plasticized gelatin solution.

7-47. The function of the cushion formed by cement is to permit intermingling of the two surfaces to be bonded. The liquid on the cushion surface, not the cushion itself, is the bonding agent. The cushion should only be large enough to assure intimate contact. Although no arbitrary soaking time can be set, regular acrylic plastic soaked an average of about 10 minutes will form a cushion deep enough to take care of any dis-

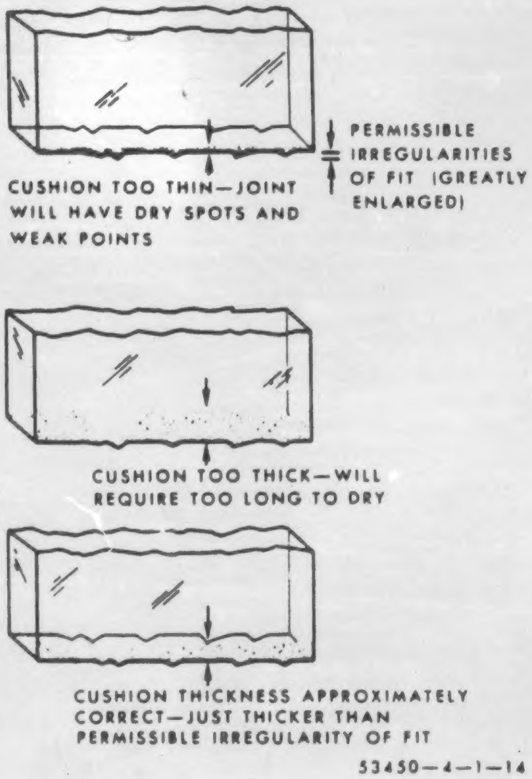

PERMISSIBLE IRREGULARITIES OF FIT (GREATLY ENLARGED)
CUSHION TOO THIN—JOINT WILL HAVE DRY SPOTS AND WEAK POINTS
CUSHION TOO THICK—WILL REQUIRE TOO LONG TO DRY
CUSHION THICKNESS APPROXIMATELY CORRECT—JUST THICKER THAN PERMISSIBLE IRREGULARITY OF FIT
53450—4—1—14

Figure 14. Proper cushion thickness.

crepancies in the fitting of the two parts, as shown in figure 14.

7-48. The interval between the soak and the assembly of the joint is perhaps the most critical of the whole cementing operation. Since these liquid cements evaporate quickly, assemble the joint as quickly as possible. If the cushion is allowed to dry, or if it is wiped free of this liquid before the joint is closed, the joint may break open or it may lack the required strength when the pressure is removed. The soak tank should be near the cementing operation, and the jigs so arranged that the operator can accurately assemble the two parts with a minimum of elapsed time.

7-49. It is important to allow a slight interval between the time the two pieces are placed in contact and the time pressure is applied. Ordinarily, 15 to 30 seconds is a sufficient interval.

7-50. In many cases, the success of a cementing job depends on the design of the jig holding the two sections in place until the joint is set. The jig should keep the two pieces firmly together but not force either of them out of shape.

7-51. First, the pressure should be great enough to squeeze all air bubbles from the joint and assure thorough intermingling of the cushions; second, it should be applied evenly all along the joint to avoid stress concentrations at any point; and third, it should be maintained to compensate for the shrinkage that takes place in the joint during setting or hardening. Since the swelling action of the cement to form the cushion causes an increase in volume, the cushion shrinks as the solvent evaporates. Avoid excessive pressure in order to prevent localized stress concentrations which cause crazing.

7-52. When placing the assembly in the jig and at intervals thereafter, it is advisable for you to examine the joint carefully. If slipping is noted before the joint has set, the pressure can still be readjusted or the job taken apart for reassembly. After the assembly has been locked in its jig, remove any excess cement and cushion which has extruded from the joint by scraping the excess onto the masking and then removing the tape.

7-53. Let the assembly remain in its jig at least 4 hours, then allow an additional 4 hours to elapse before the assembly is subjected to handling or heat treatment.

7-54. Since solvent vapor as well as the solvent itself can cause crazing, assemblies with enclosed spaces should be ventilated adequately.

7-55. A solvent joint never dries completely—that is, it will never become entirely free of solvent. If the temperature is raised, the cushion will enlarge slowly until a new equilibrium is reached, as shown in figure 15.

7-56. On cooling, the cushion will be larger and correspondingly harder, since it contains less solvent per unit of volume. Heating a solvent joint long enough to expand its cushion produces a much stronger joint.

7-57. Heat treating of cemented joints must be undertaken with caution. Heat first activates the solvent, which softens the cushion. The cushion then slowly expands as the solvent penetrates the material. In heat treating, it is important that the temperature does not approach the softening point of transparent plastics.

7-58. For heat-resisting plastic, Specification MIL–P–5425, cemented with MIL–A–8576 cement, a suitable treatment consists of 48 hours at 66° centigrade (150° F.). If this temperature causes undue dimensional changes in intricate assemblies, it may be desirable to reduce the heat-treating temperature to 33° centigrade (91° F.) and increase the length of time of heat treatment to 72 hours.

7-59. Heat treatment offers an additional advantage if the cement contains monomer, as does Specification MIL–A–8576 cement. The same process (polymerization) that causes the liquid to become solid (as in the casting of transparent plastic sheets) takes place when the joint is heated.

7-60. It is important that the joint be thoroughly hardened before machining, sanding, or polishing to remove the bead.

7-61. Use cement Specification MIL–A–25005 on plastic Specification MIL–P–8184. The surface of Specification MIL–P–8184 plastic material to be cemented must be sanded or otherwise roughened before application of the cement. For best results, use 240–400 grit sandpaper. Laboratory tests show that sanding of the surfaces to be cemented is essential to the development of adequate joint strength. It is very important that the parts fit closely before cementing. It should not be necessary to flex either piece of a joint more than a few thousandths of an inch to make the two pieces come in complete contact. This is necessary since this cement does not develop a "cushion" on Specification MIL–P–8184 plastic as does the cement used for material Specifications MIL–P–5425 and MIL–P–6886.

7-62. To prevent crazing during bonding and cementing, transparent plastic must be annealed following forming or machining. Annealing should take place not more than 24 hours prior to cementing.

7-63. Protect the area around the surface to

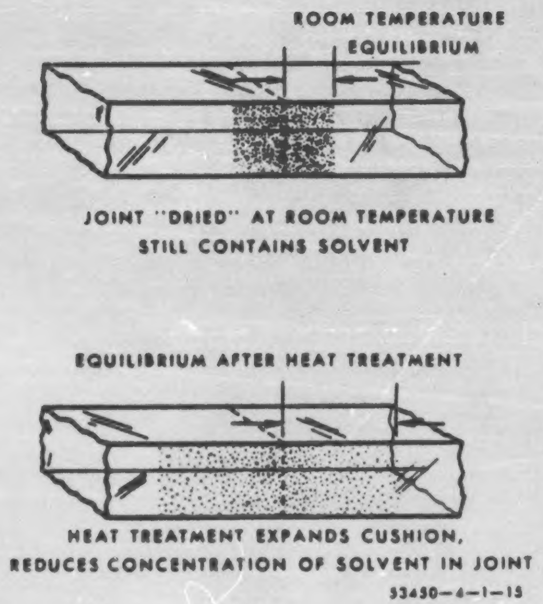

ROOM TEMPERATURE
EQUILIBRIUM
JOINT "DRIED" AT ROOM TEMPERATURE
STILL CONTAINS SOLVENT
EQUILIBRIUM AFTER HEAT TREATMENT
HEAT TREATMENT EXPANDS CUSHION,
REDUCES CONCENTRATION OF SOLVENT IN JOINT
53450—4—1—15

Figure 15. Effect of heat-treatment.

be cemented by masking with cellophane tape, fiber tape number 670, or Scotch tape. The special paper tapes used for masking against the usual type of solvent cement inhibit the polymerization of cement. Specification MIL–A–25055, and should not be used with this material.

7-64. When using cement Specification MIL–A–25005, apply it to either one or both surfaces and assemble the joint immediately. It is important that the parts be held together in a jig while the cement cures. Jigs should apply just enough pressure to force out air bubbles. Excessive or uneven pressure may force cement out of the joint, resulting in dry areas which will not bond. When cellophane masking tape is used, any excess cement forced out of the joint can be removed by scraping it onto the tape while the cement is still wet and then removing the tape.

7-65. Cement Specification MIL–A–25055 cures at a temperature of 70° Fahrenheit or higher. The joints may be handled after 4 hours, but they should be allowed to cure for 25 hours at room temperature or 4 hours at 70° centigrade (150° F.) before further machining or forming operations are started.

7-66. Keep cement Specification MIL–A–25055 out of sunlight and away from sources of heat which will increase its curing rate. Do not dispose of the cement container until the cement has set and the container is cool. Mix the catalyst and promoter with the cement in accordance with the manufacturer's instruction sheet.

7-67. This material contains a volatile liquid which is toxic if the vapor is inhaled for extended periods. Use it only with adequate ventilation. If it is accidentally spilled on your hands or skin, remove it immediately by dissolving with solvent (ethyl or isopropyl alcohol) followed by washing with soap and water. Overexposure symptoms are drowsiness, dizziness, and nausea. Treat by wrapping patient in blankets, providing plenty of fresh air, and obtaining medical assistance.

7-68. **Annealing.** Annealing of plastics consists of prolonged heating at an elevated temperature followed by slow cooling. This results in a plastic of greater dimensional stability and greater resistance to crazing. In order to obtain these benefits, it is necessary to anneal after all other fabrication procedures, including polishing, are completed.

7-69. Acrylic plastic must also be annealed following cementing and final finishing to prevent crazing from the solvent action of the cement. The annealing also materially increases the strength of a cemented joint.

7-70. Table 1 indicates the recommended heating times for annealing various thicknesses of transparent plastic sheet.

7-71. The annealing temperature for acrylic plastic, material Specification MIL–P–8257, is 60° centigrade (140° F.) for a period of 11 hours. The parts can be cooled by turning off the oven heat or by removing to a place where they will be exposed to room temperature in still air.

7-72. After elevated temperature annealing, the part must be cooled at an even rate. The rate of cooling must be slower for thick sections than for thin ones.

8. Laminated Plastics

8-1. Laminated plastic enclosures are made by bonding two layers of monolithic transparent sheet together with a soft plastic inner layer. They are installed in pressurized aircraft because of their superior shatter resistance and greater resistance to explosive decompression as compression as compared to monolithic plastic enclosures.

8-2. The inner layer material which has shown the most desirable balance of physical properties is polyvinyl-butyral. This material is manufactured in sheets of 0.015 to 0.20 inch in thickness. Several layers of this material are used to build up the thickness required for the inner layer.

8-3. Generally, the two transparent plastic outer layers are of the same thickness (balanced laminates); however, some laminates have been made in which the two outer layers were of unequal thickness (unbalanced laminates).

TABLE 1

RECOMMENDED ANNEALING TIME AND TEMPERATURE

THICKNESS (Inches)	Heating Time* in Hours for Transparent Plastics in a Forced-Circulation Air Oven Maintained at the Indicated Temperature		
	Regular Acrylic Plastic (Spec MIL-P-6886)	Heat Resistant and Modified Acrylic Plastic (Spec MIL-P-5425 and MIL-P-8184)	
	60°C 140°F	80°C 176°F	74°C 165°F
0.060 to 0.150 inclusive	10	10	
0.187 to 0.375 inclusive	10½	10½	
0.500 to 0.750 inclusive	11	11	
0.875 to 1.13 inclusive	11½	11½	
1.25 to 1.500 inclusive	12	12	
Laminated—All Thickness	11		11

* Includes period of time required to bring part up to annealing temperature.

8-4. At present, three types of approved transparent plastic materials are available for laminated materials. These are heat-resistant cast acrylic, Specification MIL–P–5425; acrylic sheet, modified, Specification MIL–P–8184; and cast polyester sheet, Specification MIL–P–8275.

8-5. The successful fabrication of laminated transparent plastic is more difficult than similar operations with monolithic transparent plastics because of the different characteristics of the plastic vinyl layers. The forming temperatures which have been found the most desirable for the various plastics are not compatible with the properties of the inner layer material. Bubbles may form in the inner layer which will not disappear when the material is cooled. The inner layer should not be subjected to temperature above 165° Fahrenheit.

8-6. One method, called flash heating, is to heat the material quickly so that the face sheets will be brought to forming temperature, formed, and cooled before the inner layer has reached its critical temperature.

8-7. The second method, called controlled forming, is to use a carefully controlled temperature just under the critical temperature of the inner layer. It is by no means the ideal forming temperature, and it results in a semicold-formed part which may incorporate an unusually high level of residual stress. These stresses, like any other which is imposed on the transparent plastic, may not be high enough to cause failures, but they will increase the susceptibility of the part to crazing. To decrease the crazing tendency, anneal the formed part at a temperature of approximately 140° to 165° Fahrenheit for a period of time sufficient to allow the residual stresses to be relieved.

8-8. Laminated transparent plastics are never formed by the vacuum method.

8-9. The same tools and equipment recommended for monolithic transparent plastic sheet are also recommended for the laminated material.

8-10. Since the exterior surfaces of transparent plastic vinyl laminates are like face sheets, the same maintenance methods recommended for the monolithic transparent sheets are followed.

8-11. To install a replacement transparent plastic vinyl laminate, employ the same mounting method used by the aircraft manufacturer.

9. Cellulose Acetate Base Plastics

9-1. In general, the methods used for fabrication, repair, and maintenance of cellulose acetate base plastics are similar to those used for acrylic plastics. In handling cellulose acetate base plastics, give attention to the following variations and additions to the recommendations already given for acrylic plastics.

9-2. Since the chemical composition of acetate base plastics differs greatly from that of acrylics, the cement used is of a different type. Generally, two types are used: solvent and dope.

9-3. Solvent type cement is generally used where transparency must be maintained in the joint. It is relatively quick-drying and is well adapted for use in making emergency repairs. However, even though the cement is quick-drying, the drying time will vary with the size of the joint and atmospheric conditions. Acetone may be used as a solvent type cement.

9-4. Dope type cement is preferred for use where the surfaces to be joined do not conform exactly. This cement softens the surfaces of a joint and, at the same time, creates a layer between the two pieces being cemented. However, it does not give a transparent joint and is slower drying than the solvent cement. It takes from 12 to 24 hours for the joint to reach full strength.

9-5. Cold, dry cellulose acetate sheets have a tendency to chip during machining. Therefore, they should be conditioned for a period of about 24 hours at a temperature ranging from 80° to 90° Fahrenheit. If water is used as a lubricant, use it sparingly, since acetate base plastics absorb it more readily than acrylics.

9-6. When cutting, you may use an automatic metal shearing device. For thin sheets, use regular hand type tin shears. Cut only after the sheet has been conditioned, as previously described.

9-7. Acetate plastics may be formed cold if the curvature is of a simple nature and has a radius not smaller than 70 times the sheet thickness.

9-8. Do not cold-form sheets below a temperature of 80° Fahrenheit. For hot-forming, the correct temperature ranges from 250° to 280° Fahrenheit. Heating time ranges from 4 to 12 minutes for sheets $^{3}/_{32}$ to $^{1}/_{4}$ inch thick. If heated to a temperature higher than 280° Fahrenheit, small parallel "sheeter" lines appear on the surface of the plastic sheet and impair its optical qualities. Be very careful when forming heated acetate base plastics, because forming temperatures are much more critical for these plastics than for acrylics. Acetate base plastics can be heated in hot air ducts or by blowing hot air onto the sheet while it is being formed.

9-9. The expansion and contraction rates of acetate base plastics are greater than those of acrylics so make greater allowances when mounting them. These plastics are affected by moisture and will swell as they absorb water. In general, allow $^{1}/_{8}$ inch per foot of panel length for expansion, and $^{3}/_{16}$ inch per foot for contraction.

9-10. It is sometimes possible to clear a badly scratched surface of cellulose acetate base plastic by applying a coating of clear varnish. When polishing and buffing, follow the same procedures as employed for acrylic base plastics, except operate the buffing wheel at 1450 rpm.

10. Hot Climate Precautions

10-1. In hot weather the transparent enclosures of parked aircraft may absorb enough heat to soften and become distorted unless certain precautions are taken. Plastic enclosures installed on aircraft parked in the sun may receive heat directly from three sources.

10-2. Transparent plastic has a property of absorbing, selectively, the heat-producing rays of the sun so that the plastic can become considerably hotter than the surrounding air inside or outside the aircraft.

10-3. Air inside an unshaded and unventilated aircraft will transfer the heat radiated by the metal members in the aircraft to the plastic enclosure by convection.

10-4. If the enclosure cover comes in contact with the transparent surfaces, there is a great tendency for the transparent plastic to craze and be scratched. This is because the cover will absorb moisture and expel harmful vapors, which in turn will craze or crack the canopy. Also, it is possible that dirt, grit, or sand may get under the cover and scratch the canopy. If the cover is such nature as to absorb heat, the transparent plastic will be heated to a temperature in excess of what it would be without the cover since there is no air circulation. Do not cover transparent plastic enclosures except for protection against windblown sand or grit, or as protection against ground temperatures above 120° Fahrenheit.

10-5. In order to prevent heat deformation of transparent plastic crew enclosures on aircraft parked exposed to the sun, the following precautions are recommended:

a. If surrounding air temperature is below 38° centigrade (100° F.), no special precautions are necessary except that, if covers are used, no part of the cover should come in contact with the transparent plastics.

b. If surrounding air temperature is between 100° and 120° Fahrenheit, enclosures should be opened sufficiently to permit free circulation of air through the aircraft and under the enclosure. If a canopy cover is needed to protect the transparent enclosure from windblown sand or grit, the cover should not come into contact with the transparent surfaces.

c. If the surrounding air temperature is above 120° Fahrenheit, the enclosure must be opened and protected from the sun by a suitable cover which does not come in contact with the transparent plastic. If possible, the aircraft should be parked in the shade.

d. To remove enclosure covers, lift them off —sliding may cause abrasion of the plastic surfaces.

11. Painting Precautions

11-1. Compounds for paint stripping, degreasing, brightening agents, and other organic solvents can cause serious damage to transparent acrylic plastics. All plastic part should be removed before applying paint stripping compounds and should not be replaced until the cleaning and painting is completed. Paint or lacquer must be thoroughly dry, since paint and lacquer can cause crazing of plastics. The plastic parts should be removed from the area where the stripping, degreasing, or painting is being done. The parts should be protected with approved soft cloth covers.

11-2. If it is impracticable to remove a plastic panel, cut a polyethylene sheet (minimum of 0.010 inch thick and containing no pinholes) to match as exactly as possible the size of the window. The polyethylene sheet should fit snugly over the surface of the plastic window. The edges must be carefully taped with masking tape (at least 2 inches wide to permit at least 1 inch of sealing width on both the plastic film and the aircraft). Make sure that no liquid or fumes can seep through to the window. It is important that the entire surface of the window be covered. Do not use cutting tools to remove the masking.

11-3. Aluminum foil is unsatisfactory as a protection from paint (and other sprays which contain solvents) because of its low resistance to tears, punctures, and pinholes. Protective coating conforming to Specification MIL-C-6799 is satisfactory as a protection from paint and other sprays which contain solvents.

12. Installation

12-1. There are a number of methods by which glass and transparent panels can be installed in aircraft. The method chosen by the manufacturer depends on the position of the panel on the aircraft and design stresses. When installing a replacement panel, follow the method of mounting given by the manufacturer.

12-2. **General Procedures.** Plastic panels are reasonably flexible; but if they are forced into a frame, high or unequal stresses may set up in certain areas of the panel. When acrylic plastics are subjected to excessive stresses, they are apt to craze. This lowers the transparency and strength of the panel. It is important, therefore, that plastics be mounted so that internal stresses are avoided or kept to a minimum. If the replacement does not fit loosely into the mounting, obtain or form a new replacement or heat and reform the panel. However, reformed panels are not placed in areas where clear vision is critically important; replace with a newly formed panel. It is not advisable to heat and reform areas, as local heating methods are likely to be only superficial and not thorough enough to reduce stress concentrations. Fitting and handling is done with masking material in place. To scribe plastic, remove the masking material. On the edges where transparent materials will be covered by attachments, remove the masking material.

12-3. Acrylic plastics expand and contract approximately three times as much as the metal channel in which they are mounted; suitable allowances must be made and specific rules must be followed during the mounting procedure. Allowances for dimensional changes with temperatures must be made. Use the values shown in

ALLOWANCES FOR DIFFERENTIAL EXPANSION AND CONTRACTION *

DIMENSION OF PANEL IN INCHES	DIMENSIONAL ALLOWANCE IN INCHES ** ***	
	REQUIRED FOR EXPANSION FROM 25°C(77°F) TO 70°C(158°F)	REQUIRED FOR CONTRACTION FROM 25°C(77°F) TO -55°C(-67°F)
12	0.031	0.050
24	0.062	0.100
36	0.093	0.150
48	0.124	0.200
60	0.155	0.250
72	0.186	0.300

*WHERE THE CONFIGURATION OF A CURVED PART IS SUCH AS TO TAKE UP DIMENSIONAL CHANGES BY CHANGE OF CONTOUR, THE ALLOWANCES GIVEN MAY BE REDUCED IF IT WILL NOT RESULT IN LOCALIZED STRESS.

**FOR DIMENSIONS OTHER THAN THOSE GIVEN USE PROPORTIONAL CLEARANCE.

***INSTALLATIONS PERMITTING LINEAR CHANGE AT BOTH ENDS REQUIRE HALF THE LISTED CLEARANCES.

53450—4—1—16

Figure 16. Expansion and contraction allowances.

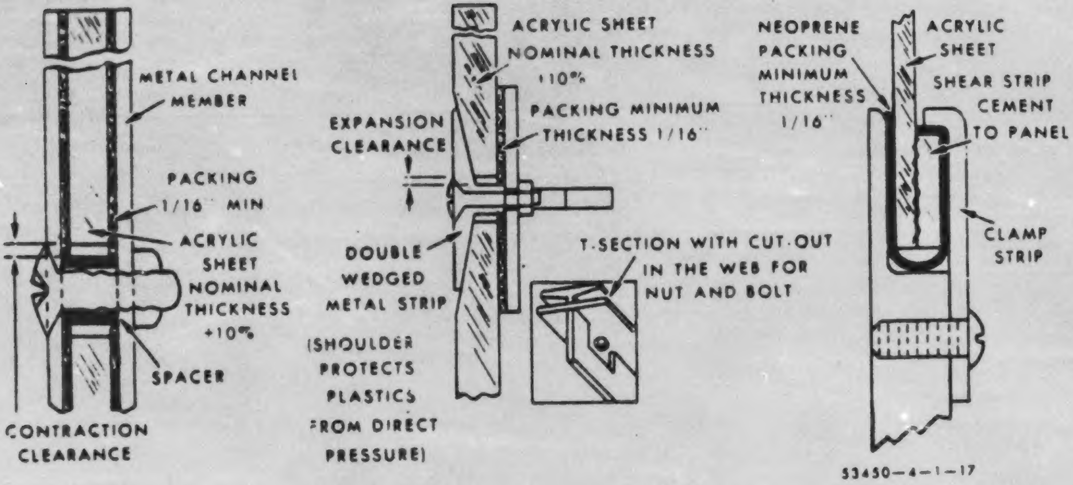

METAL CHANNEL MEMBER
PACKING 1/16" MIN
ACRYLIC SHEET NOMINAL THICKNESS +10%
SPACER
CONTRACTION CLEARANCE
ACRYLIC SHEET NOMINAL THICKNESS +10%
PACKING MINIMUM THICKNESS 1/16"
EXPANSION CLEARANCE
DOUBLE WEDGED METAL STRIP
(SHOULDER PROTECTS PLASTICS FROM DIRECT PRESSURE)
T-SECTION WITH CUT-OUT IN THE WEB FOR NUT AND BOLT
NEOPRENE PACKING MINIMUM THICKNESS 1/16"
ACRYLIC SHEET
SHEAR STRIP CEMENT TO PANEL
CLAMP STRIP
53450-4-1-17

Figure 17. Mounting plastic panels.

figure 16 as minimum clearances between frames and the plastics. If possible, avoid bolting or riveting through the plastic sheet. Channel and clamp mountings distribute stress of expansion evenly throughout the sheets. Therefore, such mountings should be used if possible. In figure 17 are drawings of some mountings. Bolt and rivet installations which go through the transparent plastic will not be used on pressurized aircraft. Where difficulty is encountered in rivet installation, bolts are to be substituted when installing replacement panels, providing the manufacturer's original strength requirements are met and the bolts do not interfere with adjoining equipment.

12-4. In bolt installations, spacers, collars, shoulders, or stop nuts are used to prevent excessive tightening of the bolt. Whenever such devices are used by the aircraft manufacturer, they should be retained in the replacement installations.

12-5. The retaining frames and mountings are of extruded type with possible sheet metal fairings to carry the contours. Repairs are limited to negligible damages. Cuts, nicks, and scratches which can be blended out without reducing the material thickness or dimension are acceptable when they are within the limitations set forth in the applicable technical order.

12-6. **Cleaning of Components.** Before installing glass or plastic into the retaining frames, the surfaces are cleaned with aliphatic naphtha, TT-N-95. Apply naphtha with a clean cheesecloth or a small paintbrush and wipe dry before evaporation can occur. Repeat cleaning until surface is free of residual film. Wipe surface dry with a clean cheesecloth or cloth. The surface is ready for you to apply tapes, adhesives, gaskets, sealants, and seals.

12-7. General procedures for removing sealants is to scrape existing material from the area with a sharp knifelike tool made of phenolic or hardwood material. When sealants are difficult to remove, apply a stripper compound, Turco 2822. Scrape off loosened sealant at short intervals and reapply stripping compound until all old sealant is removed. Remove stripping compound, using an approved solvent such as methyl ethyl ketone (MEK). Before sealing, reclean surface with aliphatic naphtha and let dry. The surface must be dry before sealing.

12-8. A considerable number of sealants require mixing with an accelerator. Directions for mixing (normally found on label of containers) should be followed closely. Thorough mixing is essential because poorly mixed compounds fail to cure. Poisonous fumes are given off during the blending process. To minimize these fumes, add the curing agent slowly, mix in small quantities, ventilate the area, do not inhale the vapors, and keep the curing agents off your hands and clothing. Consult the applicable technical order for the bench life of mixed compounds and their curing time.

12-9. Different methods of application are used to properly seal different areas of the structures. In any type of application to any area of structure, do not allow recently sealed areas to become contaminated with foreign material or allow fresh, uncured sealant to be dislodged by jarring or vibration.

12-10. Previously we mentioned how to apply sealants by the injection, faying, and filleting method on aircraft structures. Use the same requirements and procedures as given in the applicable technical order.

12-11. We have also mentioned previously that there is a specific type of smoothing compound or filler for each aircraft that is critical in aerodynamic smoothness requirements. These are manufactured in the form of pastes and putties and are basically of two types: the one-part compounds—those of the evaporative type whose chemical action controls the speed of curing and the two-part compounds—those composed of a filler and accelerator which controls the setup or curing time. Before any smoothing compound or filler is selected, the applicable technical order should be consulted for requirements.

12-12. Clean the area by removing all primers or organic paint finishes to a distance along each side of the area, as recommended by the applicable technical order. Clean and wipe the area to be filled with aliphatic naphtha brightener or a specified cleaner. Apply these cleaners with a clean cheesecloth or a brush. After the application of the cleaner, rinse clean with water, and wipe or allow surface to dry thoroughly. Repeat the cleaning process until the surface is completely free of residual film or any foreign matter.

12-13. The compounds must be measured and mixed by weight or volume in proportions recommended by the manufacturer. The directions for mixing (found on the label of containers) should be closely followed. These compounds should be mixed at room temperatures. It is also recommended that they be used within a specific time. Thorough mixing of smoothing compounds or fillers is necessary. If compounds are mixed incorrectly they may lack the proper consistency which will prevent them from curing, setting up, or hardening properly. Improper mixtures also create bubbles, causing pits or holes in the finished surface. Toxic fumes are given off during the blending process. To minimize these fumes, ventilate the area. Do not inhale the vapors.

12-14. After the surface is properly cleaned and thoroughly dried, apply the smoothing compound over the area. Use a spatula and spread it evenly. Force the smoothing compound into slots, holes, and heads of recessed fasteners. Allow a slight excess (overfill) for shrinkage during curing time.

12-15. The smoothing compound or filler must be allowed to dry thoroughly according to a time given for prevailing conditions. Consult the applicable technical order for the curing time at normal room temperatures for the specific compound being cured.

12-16. After the area is completely cured (dried), the excess compound is then removed by either machining, filing, or sanding, depending on the hardness of the compound surface. During the removal of excess compound, care must be exercised to avoid marring the aircraft surfaces to prevent unnecessary repairs to the areas. Clean the area with recommended cleaners and allow to dry thoroughly. Prime the area with a suitable primer.

12-17. **Synthetic Reinforced Edge Attachment.** Modern edge attachments on transparent plastic assemblies are made of synthetic fibers impregnated with plastic resins. The most commonly used fibers are glass, orlon, nylon, and dacron.

12-18. Reinforced laminated edge attachments are the preferred type, especially when mounting by bolts or rivets. The edges distribute the loads and reduce failures caused by differential thermal expansion.

12-19. Laminated edge attachments can be mounted by any of the foregoing methods, by drilling holes through the edge attachment material and not the transparent plastic.

12-20. The most efficient method of mounting a laminated edge attachment is by the "slotted hole" method. The slotted holes are in the edge attachment and allow for a differential thermal expansion.

12-21. Fabric loop attachments are sometimes attached to the plastic material with a cable or extrusion contained within the loop. A special extrusion is necessary to contain the loop and cable. Typical laminated edge and fabric loop attachments are illustrated in figure 18.

12-22. **Glass Enclosures.** We have previously described the construction features of acrylic transparent windows. Now let us learn the construction features of window glass used on aircraft. These glass windows are laminated panes that have inner and outer layers which are laminated with a thick transparent vinyl plastic core. The glass layers provide rigidity and a hard, scratch-resistant surface, while the core has shatter-resistance qualities. The windows may be heated or nonheated. The heated windows have a conductive film (transparent electrical resistant material) next to the window core to allow electrical heating for anti-icing and defogging. Heat is generated when an electrical current is passed through the resistant material. A heavier coating of conductive material across the top and bottom of each panel receives current from the window system transformers and feeds it across the window surface coating.

12-23. **General Safety Precautions.** While the actual installation will vary from one type of aircraft to another, observe the following precautionary techniques during installation procedures.

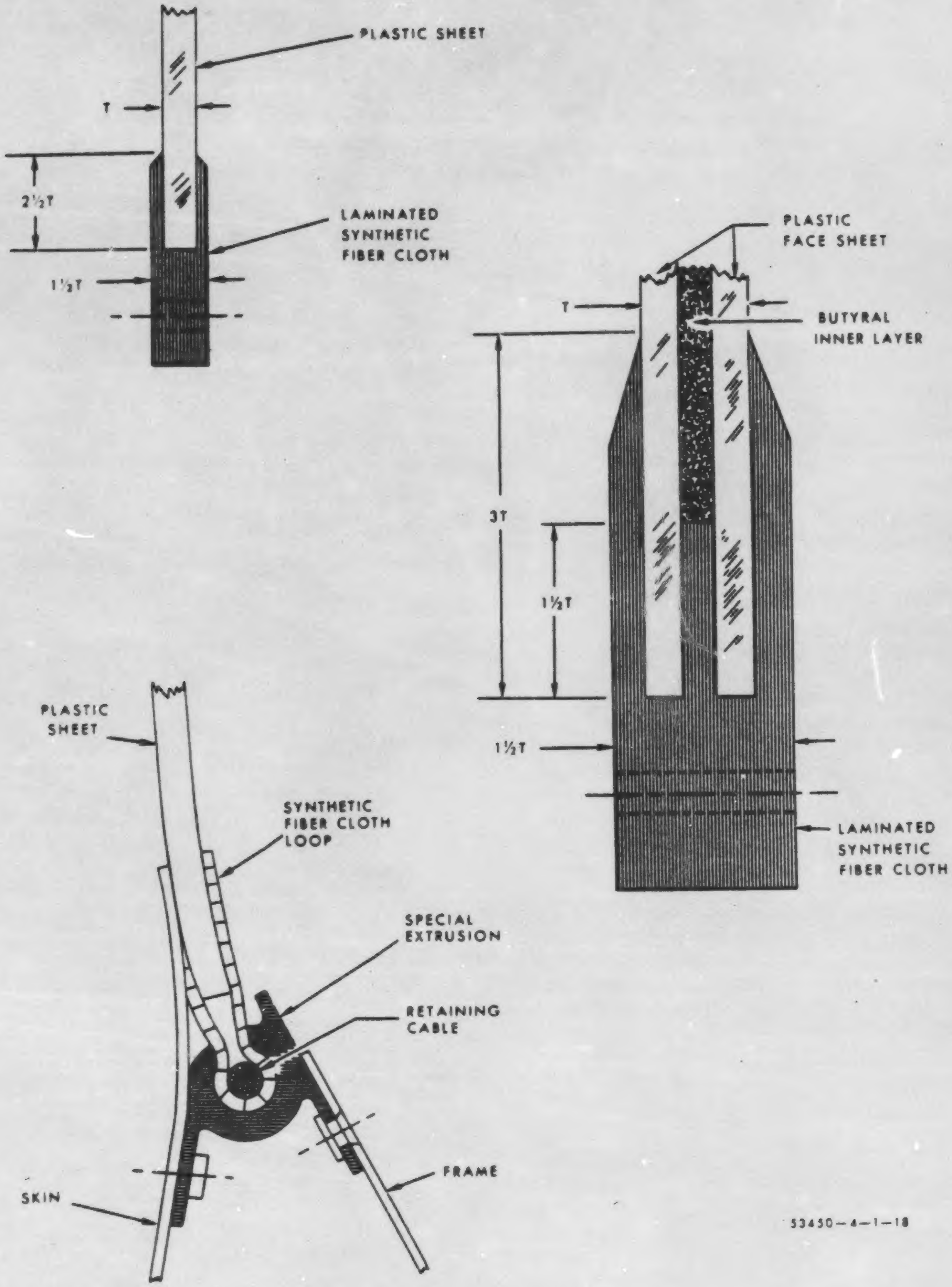

PLASTIC SHEET
T
2½T
LAMINATED SYNTHETIC FIBER CLOTH
1½T
PLASTIC FACE SHEET
T
BUTYRAL INNER LAYER
3T
1½T
1½T
LAMINATED SYNTHETIC FIBER CLOTH
PLASTIC SHEET
SYNTHETIC FIBER CLOTH LOOP
SPECIAL EXTRUSION
RETAINING CABLE
FRAME
SKIN
53450—4—1—18

Figure 18. Fabric loop attachments.

However, technical manuals for the specific aircraft should always be consulted for further recommendations and procedures.

a. Transparent plastics are brittle at low temperatures. Extra care must be exercised to prevent cracking in the course of maintenance operations. The installation should be done at normal room temperature, if practicable.

b. Use as many bolts and rivets as practical.

c. Distribute the total stresses as equally as possible along the bolts and rivets.

d. Use a fixture or jig to hold the frame.

e. Make sure the holes drilled in the plastic are sufficiently larger than the diameter of the bolt to permit expansion and contraction of the plastic relative to the frame.

f. It is important that the holes drilled in plastic be smooth and completely free from any nicks or roughness.

g. Make sure the holes in the plastic are concentric with the holes in the frame so that the greater relative expansion of the plastic will not cause binding at one edge of the hole, and prevent undue strains on any edge of the hole.

h. Use oversize spacers, shoulder bolts, rivets, and cap nuts to protect the plastic from direct pressure or excessive concentrated strains. Use the applicable technical order for the correct torque values on all bolts and nuts. When no torque values are given, tighten each nut to a firm fit, then back it off one full turn.

i. Do not successively tighten bolts or nuts. Tighten diagonally back and forth across window in a criss-cross pattern.

j. Whenever you use methyl ethyl ketone, TT–M–261, for cleaning surfaces, use it sparingly and remove all traces of it, as it will dissolve the vinyl core in the window.

k. When the reinforcement on a window fits tightly in the mounting frame, sand it off lightly. Work carefully to prevent sanding into the glass cloth.

12-24. When you are required to use or handle any of the solvents, special cleaners, paint strippers (strong alkalies and acids), etchants (corrosion removers containing acids), or surface activation materials (alodine 1200), observe the following personal safety precautions:

a. Avoid prolonged breathing of solvents or acid vapors. Solvents and acids must not be used in confined spaces without adequate ventilation or approved respiratory protection.

b. Never add water to acid. Always add acid to water.

c. Do not mix chemicals, except as prescribed by the procedures given.

d. Locate the nearest water supply before starting to work.

e. Avoid prolonged or repeated contact of solvents, cleaners, etchants (acid) with skin. Rubber or plastic gloves should be worn when using the solvents. When it is necessary to work overhead, you must wear goggles or plastic face shields and rubber raincoats and rainhats.

f. When mixing alkalies with water or other substance, use containers which are made to withstand heat generated by the process.

g. Paint stripper, etchant, or other acid materials must be washed off immediately from body skin or clothing.

h. Materials splashed in the eyes must be promptly flushed out with water and the injured person sent to the medical officer or hospital for further treatment.

i. Wash hands before rubbing your eyes, touching your skin, or smoking, etc.

j. Be sure to wash with soap and water after working.

k. Wear goggles or a face shield when you drill, grind, file, or use any power tool.

12-25. For additional information read TO 1–1A–12, *Fabrication, Maintenance and Repair of Transparent Plastics.*

CHAPTER 2

Fiberglass Enclosures and Parts

PLASTIC CARS the transportation of tomorrow? Except for a few components, such as engines and transmission gears, the cars of the future could well be made entirely of plastics. The use of plastic material in the construction of today's cars is not limited only to interior plastics, such as panels, upholstery, fasteners, etc., but plastics reinforced with fiberglass are being used to make chassis parts. Adhesive bonding is stronger than metal welds; thus, those pesky squeaks and rattles from loose bolts and screws are being eliminated. Fiberglass already is used in the manufacture of many aircraft components and parts such as radomes, antenna covers, junction boxes, wingtips, tanks, and heater ducts. It is unequaled in the strength-to-weight ratio and has the ability to allow radio and radar waves to pass through. It is easy to manufacture into different shapes, is immune to mildew, and has good weather-resistant characteristics.

2. In this chapter you will study the construction features, evaluation of damage, repair materials, tools, and equipment used in the repair of fiberglass components. Information on maintenance procedures, inspections, and safety precautions are also discussed.

3. Typical repair techniques are explained to help you understand the maintenance and repair of fiberglass components and parts. The information given will greatly help you to acquire the skill needed in repairing fiberglass assemblies.

13. Mat Molded

13-1. Fiberglass is manufactured from specially processed glass balls by a process in which the glass is turned into fibers, the end products being cloth, molded mats, or yarn, as shown in figure 19.

13-2. Fiberglass is durable, flexible, fireproof, and very stable. Glass fibers have a high tensile strength; and because of the moisture resistance quality, they will not shrink, stretch, rot, or decay. Fiberglass resists most acids, alkalis, oils, solvents, sea water, and corrosive atmospheres.

13-3. **Construction Features.** Glass fibers act as a reinforcement for epoxy or polyester resins in the construction of fiberglass assemblies. The assemblies are fabricated by a process wherein the chopped fibers are molded around a form, bonded together by use of a resin, and cured under heat and pressure. *Molded mat fiberglass* is made of short chopped fibers (fibers are in different lengths and are in a random pattern) molded in a mat form, as shown in figure 20. *Mat molded* fiberglass is made by using fiberglass mat (pattern is cut from flat mat), adding the desired resin, and placing the material between a male and female die. It is then cured under heat and pressure, as shown in figure 21. Nonstructural parts, such as junction boxes, relay shields, and ducts, are manufactured from mat molded fiberglass.

13-4. **Damage Evaluation.** To determine the extent of damage, the affected area should be wiped with a clean cloth saturated with methyl ethyl ketone (MEK). If there is paint on the surface, remove it by lightly sanding the area with number 280 grit sandpaper. Clean the area again, being sure to remove all grit. Careless handling and vibration are the two causes of damage to parts. Damage to mat molded parts usually consists of a hole or a crack in the assembly. The length and size of the hole determine whether it is a minor or major repair. Figure 22 illustrates a typical minor damage. In the classification of repairs, longer cracks and larger holes are considered as major repairs. The applicable section in the –3 technical order for the specific aircraft will give you the information to help you in classifying the damage.

13-5. **Material, Tools, and Equipment.** The following paragraphs will give you information on the uses, characteristics, and functions of materials, tools, and equipment you will use in the repair of mat molded assemblies.

13-6. Polyvinyl alcohol (PVA) film is a plastic material used as a parting agent between the saturated fiberglass mat and the metal used to

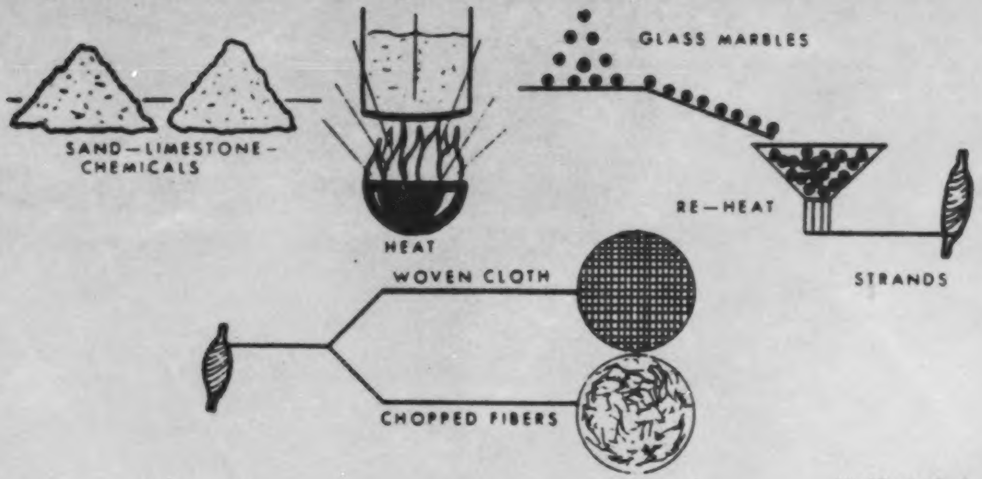


Figure 19. Manufacturing process of fiberglass.

hold the material in place during the curing process. It is water soluble and can easily be removed from the repair when necessary. You will note that the film has a tendency to curl on the edges and looks cloudy. When heated it will stretch to contours and all wrinkles can be smoothed out. It is used on polyester resin. The film can be heated to 400° Fahrenheit in the curing of repairs.

13-7. Cellophane and polyvinyl chloride sheets are plastic parting agents used in places similar to those in which PVA film is used. They will not stretch, but will wrinkle and cause imperfections on the surfaces. They tend to harden when heat is applied. The material is transparent and very clear. The parting sheets must be at least 0.003 inch thick for repair use. For the most part, you will use this material where you have a single curvature and flat surfaces.

13-8. Fiberglass mats are sheets of molded mats made from fiberglass threads and are used in the repair of mat molded assemblies. They are used to build up the section beveled out of the assembly during repair procedures.

13-9. A polyester type resin is used to bond the molded mat to the assemblies when making repairs. It is manufactured from one of the family of hydrocarbon chemicals and comes in liquid form. Many companies manufacture it under various trade names. All resins must meet Specification MIL–7575. They are not used in their original state for the repair but must have other chemical materials added so that they will adhere and harden (cure).

13-10. A catalyst is a chemical compound added to a resin mixture to start a chemical reaction needed in the curing process. It is added to the mixture last as it will start its reaction as soon as it is combined with the other ingredients.

13-11. ~~An accelerator~~ Cobalt (sometimes called a promotor) is a chemical compound used in the resin mixture to speed up or hasten the chemical reaction caused by addition of the catalyst. The accelerator is added to the mixture before addition of the catalyst.

13-12. Resins and catalysts should be stored in a cool place—a refrigerator or a deep freeze—as recommended by the manufacturer. Refrig-

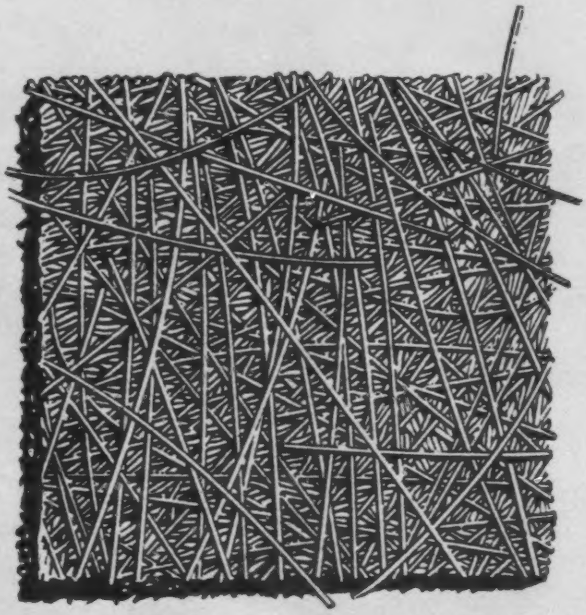


Figure 20. Fiberglass mat.

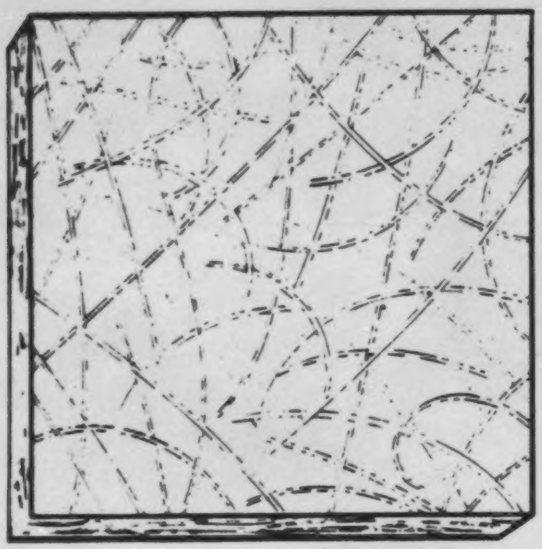


Figure 21. Mat molded fiberglass.

erated storage prolongs the life of resins and catalysts over that of the same materials stored at room temperature. Mixing should be done with the materials at room temperature to insure homogeneity. Any resin (at room temperature) which appears to be jelled or changed from its original viscosity must not be used. Most resins and catalysts have a shelf life. Some manufacturers date the material on the containers. Personnel receiving resins and catalysts must be sure they are dated or must date them immediately and then adhere to the length of shelf life given in the technical order. Old materials may cause failures in a repair.

13-13. Resins. ~~accelerators,~~ promoters and catalysts are all usually measured by gram weight to insure that the correct proportion of each ingredient is used for the mixture. It is very important that the right amounts of each are used, as the addition of too much of any one would cause the mixture to cure improperly. A scale such as the one illustrated in figure 23 is the most accurate measuring method that can be used. Amounts can be correctly measured by placing a paper cup on the scale, weighing it, and then pouring the desired amount of each ingredient needed into the cup. Combine the mixture by stirring with a wooden paddle. A paddle can be made of any material that will not cause a chemical reaction with the resin mixture.

13-14. Any piece of metal that will give satisfactory holding strength can be used in repair procedures. Its primary purpose is to hold the repair materials under slight pressure and in the original contour when clamped to the assembly being repaired.

13-15. Use ordinary C-clamps to hold the metal plates and repair in place. Tighten the clamps to a snug fit, but never overtighten.

13-16. Any air circulating furnace will do a satisfactory job in curing repairs. The furnace should be capable of maintaining a temperature of 220° to 250° Fahrenheit.

13-17. Tools needed for repairing are a compass, straightedge, knife, scissors, spatula, air drill and bits, rotary file, and disc sander.

13-18. Other curing equipment that can be used for the repair will be given in later paragraphs.

13-19. **Repair Methods.** The following procedures are typical and can be used to repair a mat molded assembly. When you are to work on an aircraft part, select the correction section for the repair in the technical order for the specific aircraft and follow those procedures.

13-20. Inspect the part, determine the type of damage, and then select the method of repair you should use. Remove the paint or protective coating from around the damaged area. For a crack repair, stop drill the end or ends of the crack. The size of the drill must not be smaller than ⅛ inch and not larger than $^3/_{16}$ inch. Use figure 24 for laying out your repair. Use the dimensions given and sand the damaged area. General procedures to follow are:

(1) Remove one-third of the material from both sides of the damaged area.

(2) Bevel the area 15° to 45°, as shown in figure 24.

(3) Sand ½ inch beyond the beveled area.

(4) Cut two pieces of PVA film large enough to cover the repair area.

(5) Cut two pieces of aluminum metal large enough to cover the repair area. These will be used to hold the repair in place during the curing time.

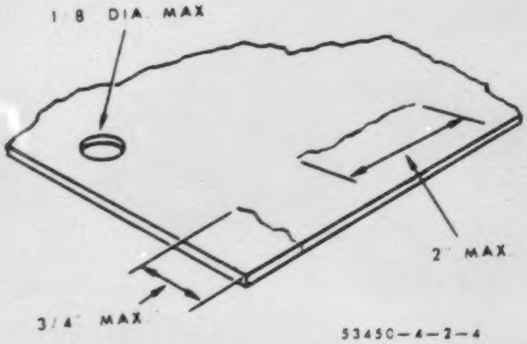


Figure 22. Typical damage to mat molded parts.

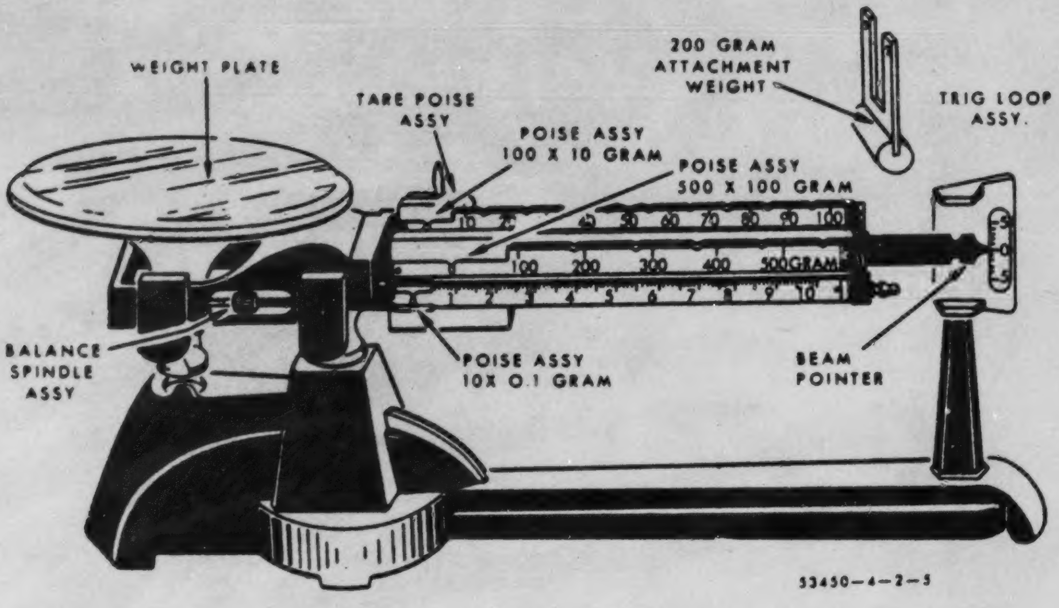

200 GRAM ATTACHMENT WEIGHT
WEIGHT PLATE
TARE POISE ASSY
POISE ASSY 100 X 10 GRAM
POISE ASSY 500 X 100 GRAM
TRIG LOOP ASSY.
BALANCE SPINDLE ASSY
POISE ASSY 10X 0.1 GRAM
BEAM POINTER
33450—4—2—5

Figure 23. Triple beam balance scale.

13-21. Start the air-circulating furnace and set the temperature at 220° Fahrenheit. If other means to cure the repair are to be used, this step is unnecessary.

13-22. Select and prepare the resin mixture. Be sure to prepare the resin as prescribed in the technical order. Too much catalyst or promoter will cause the resin to burn or crystalize.

a. Cut the mat fiberglass to correct size of repair. Cut enough pieces of material to build up the beveled out area to its original contour.

b. Saturate each piece with resin.

13-23. Insert the saturated mat fiberglass material into the repair area as in figure 25. Then use the following steps:

(1) Do one side at a time.

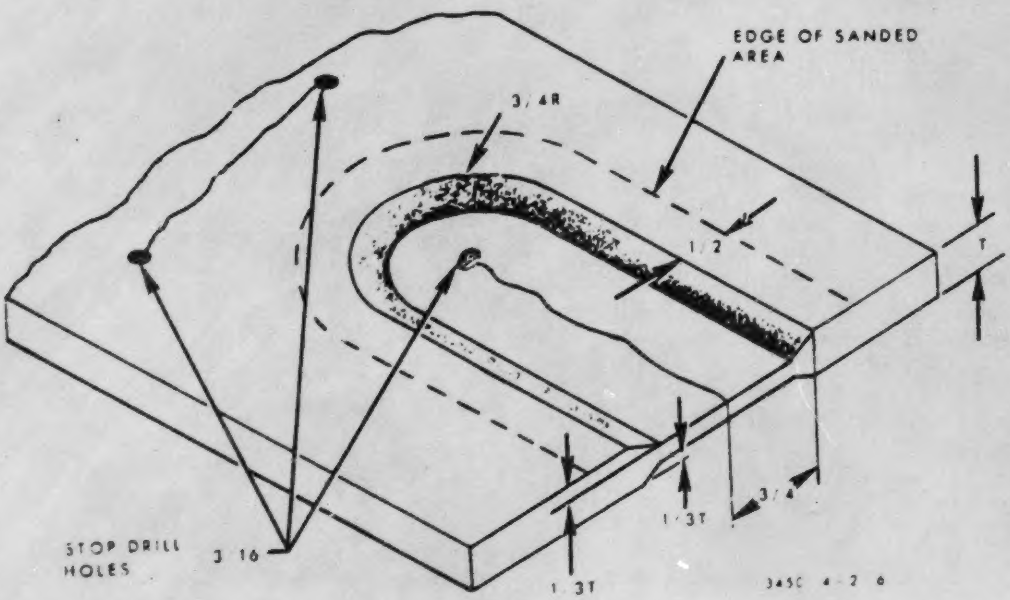

EDGE OF SANDED AREA
3/4R
1/2
T
1/3T
3/4
1/3T
STOP DRILL HOLES
3/16
345C 4-2-6

Figure 24. Preparation of damaged area, mat molded.

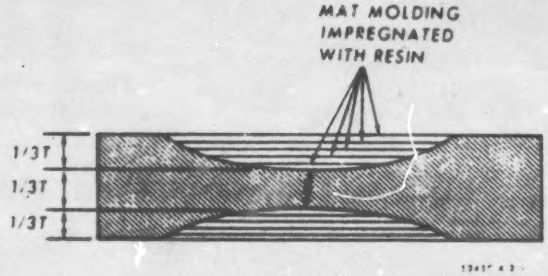


Figure 25. Insertion of precut saturated sections.

(2) Cover each side with the precut PVA film.

(3) Place the prepared metal plate on each side of the repair as it is completed.

(4) Secure the repair in place by the use of C-clamps. Tighten to a snug fit—never overtighten.

13-24. A repair is cured by applying heat. There are several methods:

a. Place the assembly in the preheated oven and leave for at least 1 hour. (Check the applicable technical order or manufacturer's instructions for the resin you are using). After the prescribed time, remove the assembly from the oven and let it cool at room temperature. Disassemble the repair by removing the C-clamps, metal plates, and the PVA film. Send both sides of the repair smooth and to the original contour of the part.

b. To maintain the correct temperature for curing, use heat lamps of 250 to 350 watts or a battery of infrared lamps. A Pyrometer and thermocouple wire are needed to maintain the correct temperature on the repair. This will be shown and explained later in this chapter.

c. Cure for a room-temperature repair mixture takes approximately 4 hours at a temperature of 77 ° Fahrenheit. Remember, humidity will affect the length of curing time.

13-25. **Quality Inspection.** After the repaired section has been properly cured and cooled to room temperature, inspect it. As you check the repair, notice the short (various lengths from ½ to 2 inches) chopped strands of fiberglass embedded in the hard plastic. The fiberglass strands should be in a random pattern; the repair should have a hard surface and should give a metallic ring when struck with a coin (quarter) or a light aluminum hammer. If there is an indication of insufficient cure, additional heating and curing time is necessary. Check for large blisters, starved areas, and surface pits (pits should not be larger than ¼ inch in diameter). Check the applicable technical order for permissible defects allowable.

13-26. **Safety Precautions.** General precautions to be followed in the shop include the use of face shield, goggles, rubber apron, rubber gloves, and care in mixing of resins. Do not inhale the fumes during the mixing procedures. Never mix the catalyst and accelerator together; such a mixture may cause an explosion. Always mix the accelerator with the resin, then add the catalyst to that mixture. Remember, protection of the skin and the wearing of a respirator are important at all times when working with plastics. All chemicals should be identified, properly labeled, and placed in suitable containers. When you handle resin impregnated materials and solvents, wash with soap and water at frequent intervals, as this will prevent infections and irritations of the skin. Be sure you have plenty of ventilation in the room you work in. The sanding and scraping on glass fabric laminates give off a fine dust that may cause skin irritation. Breathing an excessive amount of this dust may be injurious; therefore, precautions to protect your skin and respiration must be observed.

14. Laminates

14-1. Many fibrous materials such as cotton, nylon, asbestos, glass, and various other synthetic fibers, may be used as a reinforcement for plastic laminates. Some experimental work is being conducted in the use of other types of materials, such as glass flakes, as reinforcing agents. Currently, however, glass fiber is the reinforcement most commonly used in aircraft applications. Some asbestos and cotton fibers are also being used. Most of the repairs are to plastic laminates reinforced with glass fibers.

14-2. **Construction Features.** We have mentioned the use of chopped fiber mat as a reinforcement in plastic. Fibrous glass reinforcement also comes in the form of woven fabric, continuous fiber mat, wrap, or roving. The specific form used will depend upon the application involved and the strength properties required. Glass fabrics are made from either continuous filament or stable fiber yarns. For aircraft applications, glass fabric made from continuous filament yarns is used almost exclusively. Fabrics are woven to have different strength properties in two directions—that is, parallel and perpendicular to the warp direction.

14-3. Fiberglass cloth is used for reinforcement because of its structural strength properties. There are approximately six characteristics that you must consider when using fiberglass cloth for repairs.

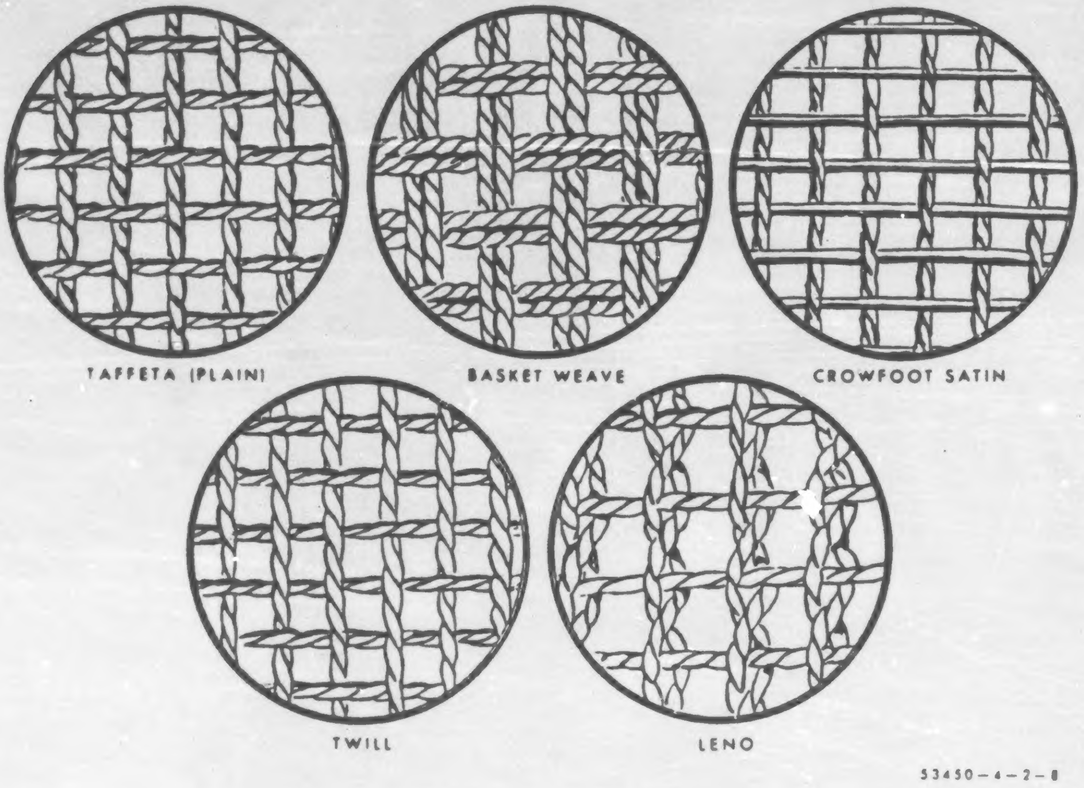


Figure 26. Weave pattern for fiberglass.

(1) The thickness of fiberglass cloth varies from 0.0010 to 0.38 inch thick.

(2) The weight of fiberglass cloth is computed by the square yard and varies from 1 ounce to 2 pounds per square yard.

(3) Note the weave types. There are five commonly used weave patterns, as shown in figure 26.

(4) Many yarn sizes and twists are in use and are determined by weight and thickness of the fabric.

(5) A finish is usually applied after the glass cloth has received its initial treatment. Each glass fabric has a specific finish that meets the requirements of the resins to be used.

(6) Another structural property of fiberglass cloth to consider is the strength of the fiberglass strands of which it is constructed. (See fig. 27).

14-4. We mentioned that a finish is applied to the glass cloth without regard to its application. This paragraph will explain why it is put on the glass cloth. The glass filaments are very susceptible to abrasion by one another. To prevent the abrasion a lubricant is applied immediately after forming. The filaments in the strands are bonded together by a coupling agent known as a finish. The coupling agent (finish) is applied to provide adhesion for the resin. The reason for the finish is that resins do not adhere to the glass well; thus the treatment must act as a lubrication and bonding agent between the filaments. Two general types of finishes are used: silanes and chromes. The choice of which finish is used is determined by the strength required and the type of resin to be used.

14-5. There are many different finishes for fiberglass, each of which is used for different conditions and circumstances and is normally applied after a heat-cleaning process.

a. T–31 finish. T–31 is saturated with a silane type chemical and carefully cured. It is used where polyester, epoxy, phenolic, and melamine resins are to be the bonding resins.

b. 108 Finish. The 108 finish is used where no heat-treatment or heat-cleaning is necessary. The fabric is dipped in a water emulsion of silicone oil and placed in a drying oven. This finish is used to prevent moisture from entering the fabric through the exposed cut edges. Moisture causes deterioration of the fabric's wet strength capability. This finish is also used on fabrics to be coated with vinyl compounds or natural and synthetic rubbers.

Fabric (Type)	Construction (Warp & Fill)	Weight Oz/sq yd	Thickness (inches)	Breaking Strength (lbs/inch) Warp	Fill	Roll Length (yards)
120	60 x 58	3.16	.004	125	120	250
128	42 x 32	5.92	.007	250	200	250
181	57 x 54	8.74	.009	340	330	125

Figure 27. Strengths of fiberglass.

c. 111 Finish. This finish consists of low temperature partial removal of the fabric yarn sizing, during which some of the oils and starch volatile and the starch that is left is caramelized. It has a tan color and is used primarily in melamine laminates.

d. 114 Finish. After heat cleaning, the fabric is saturated with methacrylate chromic chloride and dried. This finish is for use with polyester laminates where maximum dry strength and retention of wet strength are not necessary factors.

e. 136 Finish. This finish is heat-cleaned and then saturated with silane type chemical. Then it is dried under controlled conditions which leave a vinyl triethoxysilane on the glass surface. The primary use of this finish is for silane and polyester laminates; it has excellent dry and wet strength properties.

f. A–172 Finish. After heat-cleaning, the fabric is immersed until saturated with silane type chemical and dried under controlled conditions. Vinyl-triethoxysilane remains on the surface of the glass. This finish is used with polyester resins and meets MIL–P–8013–B and MIL–F–9084–A specifications.

g. 210 Finish. This finish requires a special method that removes the oil and starch binder to a level of 0.12 percent or less.

h. I–516 Finish. This finish is similar to type 111 finish except it has a 0.1 to 0.2 percent further ignition loss. This increases the physical and electrical properties above the 111 finish.

i. A–1100 Finish. The fabric is saturated with aminetype vinylsilane and dried. A–100 is used with phenolic, epoxy, and melamine resins. Laminates having this finish meet Specifications MIL–R‑9299 and MIL–R–9300–A and are used with high-temperature phenolics.

j. GARAN RS–49 Finish. The fabric receives a heat-cleaning finish and is then run through a silane type chemical. After drying, vinyl-triethoxysilane remains on the surface of the glass. This finish meets Specifications MIL–P–8013–B and MIL–F–9084–A.

k. VOLAN–A Finish. After receiving heat-cleaning treatment, the glass is saturated with methacrylate chromic chloride so that the chrome content of the finished fabric is between 0.03 and 0.05 percent. It is washed after the methacrylate chromic chloride is cured to remove the soluble chlorides that are formed. This finish is used with polyester, epoxy, and phenolic laminates, which require good wet and dry strength properties. Polyester laminates meet Military Specifications MIL–P–8013–B and MIL–F–9084–A.

14-6. The properties of glass reinforced laminates are affected by such things as conditions of exposure (temperature, moisture, and weather), thickness of laminates, and variables of fabrication. In many applications, laminates are exposed to moisture in the form of either high humidity or free water. The amounts of moisture absorbed are generally quite small; but under long exposure the strength properties are decreased. The amount of decrease depends on the type of finish applied to the fabric, exposure site and type of resin, as well as the reinforcing agent used. Laminates made with polyester, epoxy, phenolic, and silicone resins have withstood up to 3 years weathering without severe reduction in strength properties. Laminates should be kept painted to reduce erosion of the resin on the exposed face. Moisture in laminates will reduce the electrical properties. The strength properties of glass fiber base laminates at elevated temperatures are dependent on the laminating resin used. The polyester resins conforming to Military Specification MIL–R–7575 vary in heat resistance, but most of the resins produce laminates that retain a large share of their strength at room temperature and as high as 200° Fahrenheit. A few of them retain much of their room temperature strength at even 300° Fahrenheit. Epoxy resins conforming to Specification MIL-R-9300 also vary in heat resistance. Heat-resistant resins are being designed for high-temperature use.

14-7. Fiberglass is used in many areas of the aircraft. Parts and assemblies constructed of fiberglass include junction boxes, doors, panels, brackets, etc. Many of these are used in areas that are load-carrying members. Due to the strength and dielectrical quality of fiberglass cloth, it is used as reinforcing material in facing of sandwich constructed and solid wall type radomes, ducts, and wingtips. Glass fiber plastic laminates are widely used in fabricating aircraft antenna hous-

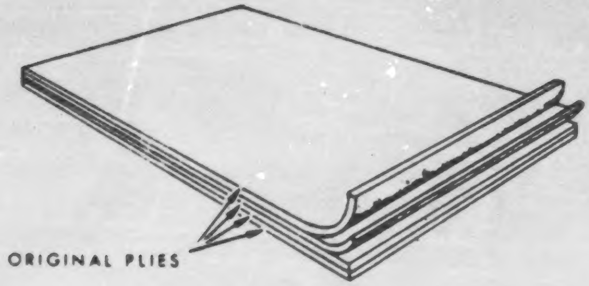


Figure 28. Solid laminate construction.

CHART 1
LAMINATED FIBERGLASS DAMAGE EVALUATION

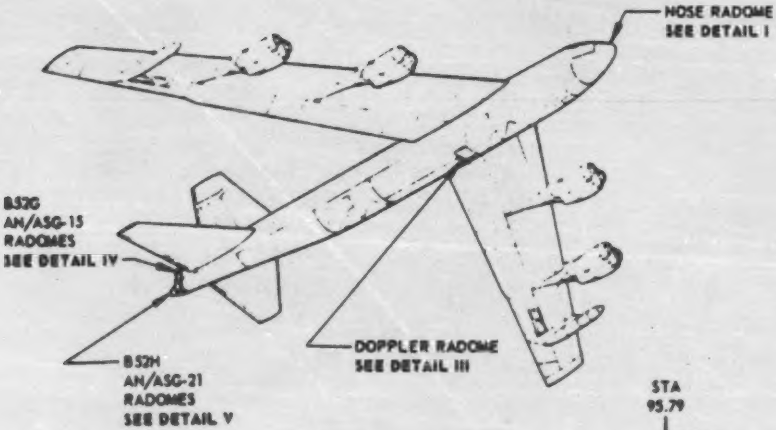
TYPE OF DAMAGE	ALLOWABLE DAMAGE	REPARABLE DAMAGE	REPAIR PARAGRAPH
SCRATCHES, SURFACE CUTS OR EROSION	SCRATCHES, SURFACE CUTS OR EROSION WHICH DOES NOT PENETRATE INTO THE GLASS FABRIC. NOTE REPAIR RAIN EROSION RESISTANT COATING AS OUTLINED IN PARAGRAPH 1-101 OR CONDUCT REPAIR AS OUTLINED IN PARAGRAPH 10-14	SCRATCHES, SURFACE CUTS OR EROSION WHICH PENETRATE INTO THE FIRST PLY OF THE GLASS FABRIC SHALL BE REPAIRED AS FOLLOWS: DAMAGE LESS THAN 1/2 INCH IN LENGTH DAMAGE GREATER THAN 1/2 INCH IN LENGTH	10-14 10-15
CRACKS	NOT ALLOWABLE	ALL CRACKS SHALL BE REPAIRED AS FOLLOWS: DAMAGE LESS THAN 1/2 INCH IN LENGTH DAMAGE GREATER THAN 1/2 INCH IN LENGTH	10-39 10-40
DENTS	ANY DENT LESS THAN 3 INCHES IN DIAMETER IS ALLOWABLE PROVIDED IT IS NOT ACCOMPANIED BY A SKIN PERFORATION OR SKIN CRACK. DENTS OVER 3 INCHES IN DIAMETER ARE ALLOWABLE PROVIDED THEY ARE NOT ACCOMPANIED BY A SKIN DELAMINATION, SKIN PERFORATION OR SKIN CRACK. NOTE ALLOWABLE DENTS SHALL BE NO CLOSER EDGE TO EDGE THAN THE SUM OF THEIR WIDTHS	DENTS EXCEEDING THE ALLOWABLE DAMAGE LIMITATIONS ARE REPARABLE AS FOLLOWS: DAMAGE LESS THAN 1/2 INCH IN DIAMETER DAMAGE GREATER THAN 1/2 INCH IN DIAMETER	10-39 10-40
PERFORATIONS	NOT ALLOWABLE	LAMINATED FIBER GLASS SKIN PERFORATIONS SHALL BE REPAIRED AS FOLLOWS: DAMAGE LESS THAN 1/2 INCH IN DIAMETER DAMAGE GREATER THAN 1/2 INCH IN DIAMETER	10-39 10-40
DELAMINATIONS	SKIN DELAMINATIONS LESS THAN 3 INCHES IN DIAMETER ARE ALLOWABLE PROVIDED THEY ARE NO CLOSER EDGE TO EDGE THAN THE SUM OF THEIR WIDTHS AND ARE NOT ACCOMPANIED BY A SKIN PERFORATION OR SKIN CRACK	SKIN DELAMINATIONS WHICH EXCEED THE ALLOWABLE DAMAGE LIMITATIONS SHALL BE REPAIRED AS FOLLOWS: DAMAGE LESS THAN 3 INCHES IN DIAMETER DAMAGE GREATER THAN 3 INCHES IN DIAMETER	10-20 10-40
MULTIPLE DAMAGE	MULTIPLE DAMAGE IS ALLOWABLE IF IT DOES NOT EXCEED THE ALLOWABLE DAMAGE LIMITATIONS. NOTE MULTIPLE DAMAGE OR REPAIRS SHALL COVER NO MORE THAN 20 PERCENT OF THE TOTAL AREA.	THE ENTIRE OUTER GLASS FABRIC PLY MAY BE REPLACED, IF REQUIRED, TO MEET THE ALLOWABLE REPAIR AREA LIMITATION.	10-41

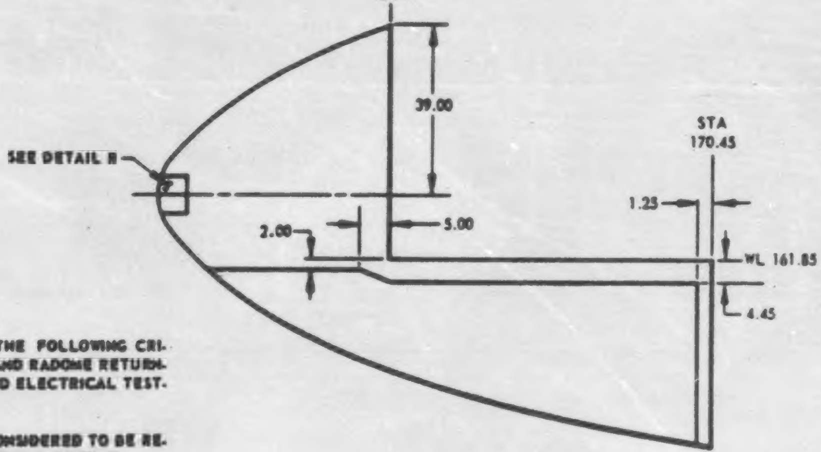
NOTE

FOR DAMAGE EVALUATION OF WING TE FILLER LAMINATES, SEE PARAGRAPH 10-41C

FOR AN/ASG-15 RADOME REPAIR RESTRICTIONS, SEE FIGURE 10-8A

53450-4-2-C1


NOSE RADOME
SEE DETAIL I
B52G
AN/ASG-15
RADOMES
SEE DETAIL IV
DOPPLER RADOME
SEE DETAIL III
B52H
AN/ASG-21
RADOMES
SEE DETAIL V


STA
95.79
39.00
STA
170.45
SEE DETAIL II
1.25
2.00
5.00
WL 161.85
4.45

NOSE RADOME A

DETAIL I

NOTE

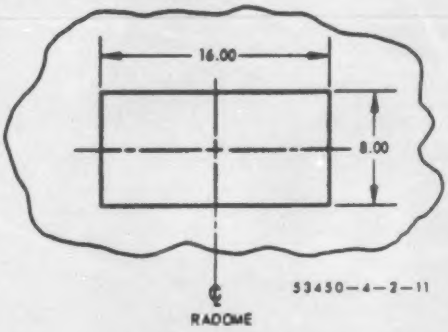
ALL RADOMES EXCEEDING THE FOLLOWING CRITERIA SHALL BE REPLACED AND RADOME RETURNED TO DEPOT FOR REPAIR AND ELECTRICAL TESTING

FIELD LEVEL REPAIRS ARE CONSIDERED TO BE REPAIRS NOT REQUIRING ELECTRICAL TESTING

ELECTRICAL TESTING OF A REPAIRED RADOME WILL NOT BE REQUIRED IF REPAIR MEETS ONE OF THE FOLLOWING CONDITIONS:

- REPAIR NOT WITHIN DESIGNATED WINDOW AREA
- SCARS, SCRATCHES, SURFACE ABRASIONS, OR MINOR RAIN EROSION NOT PENETRATING THROUGH THE FACING (FIRST PLY) AND REPAIRED PER PARAGRAPH 10-14
- REPAIRS TO OR REPLACEMENT OF RAIN EROSION RESISTANT COATING

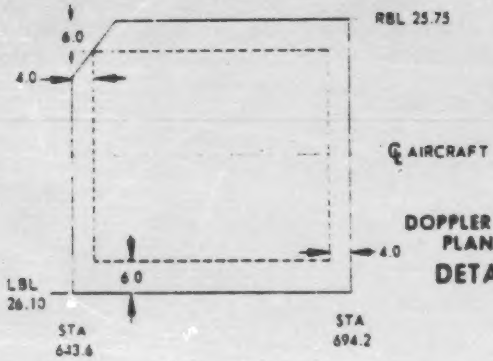
A CRITICAL WINDOW AREAS OF NOSE RADOME ARE THE AREAS SHOWN SHADED. MOISTURE REMOVAL OF NOSE RADOME SHALL BE ACCOMPLISHED PER T.O. 1-1-24, EXCEPT THAT OUTER PLY SHALL NOT BE REMOVED IN CRITICAL WINDOW AREAS


16.00
8.00
53450—4—2—11
℄
RADOME

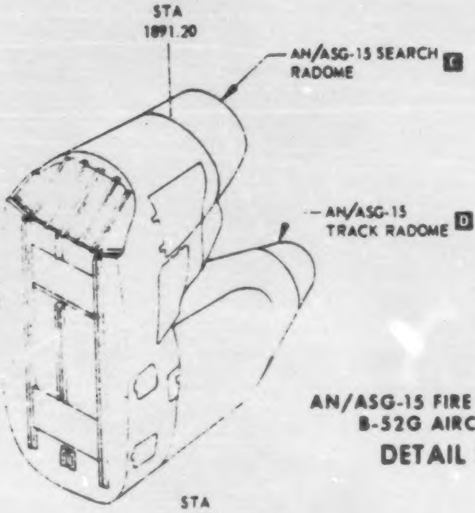
FRONT VIEW

DETAIL II A

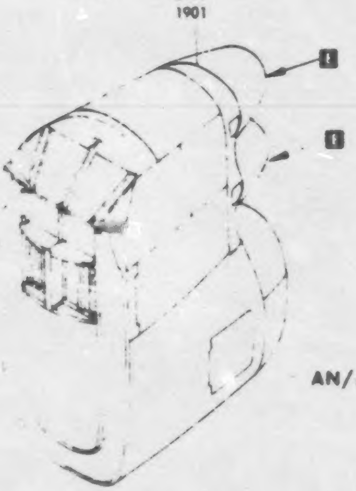
Figure 29. Radome repair restrictions.



DOPPLER RADOME B
PLAN VIEW
DETAIL III



AN/ASG-15 FIRE CONTROL
B-52G AIRCRAFT
DETAIL IV



AN/ASG-21 FIRE CONTROL
B-52H AIRCRAFT
DETAIL V

NOTE

B CRITICAL WINDOW AREA OF DOPPLER RADOME IS SHOWN SHADED; HOWEVER, REPAIRS ARE ALLOWED WITHOUT ELECTRICAL TESTING PROVIDED THEY DO NOT EXCEED THE FOLLOWING LIMITS:

- MAXIMUM SIZE OF PATCH OUTSIDE WINDOW AREA 9.0 SQUARE INCHES
- MAXIMUM SIZE OF PATCH INSIDE WINDOW AREA 3.2 SQUARE INCHES
- ALL PATCHES SHALL BE CIRCULAR SHAPED
- MINIMUM DISTANCE BETWEEN PATCHES 12 INCHES
- CORE FILLING PERMITTED PROVIDED MAXIMUM AREA DOES NOT EXCEED .25 SQUARE INCHES (APPROXIMATELY 4 CELLS)

C AN/ASG-15 SEARCH RADOME, DETAIL IV, B-52G AIRCRAFT. THE RADOME IS OF SOLID LAMINATE CONSTRUCTION AND MAY BE PATCHED ANYWHERE ON ITS SURFACE WITHIN THE FOLLOWING LIMITATIONS:

- ALL PATCHES SHALL BE CIRCULAR SHAPED
- MINIMUM SIZE OF PATCH 2.00 INCHES IN DIAMETER
- MAXIMUM SIZE OF PATCH 5.00 INCHES IN DIAMETER
- MINIMUM SPACING BETWEEN PATCHES SHALL BE 6.00 INCHES
- MAXIMUM OF 2 SKIN PLIES MAY BE REPAIRED

D AN/ASG-15 TRACK RADOME, DETAIL IV, B-52G AIRCRAFT. NO PATCHING ALLOWED WITHOUT ELECTRICAL TESTING DUE TO BORESIGHT ERROR REQUIREMENTS. DEFECTS IN EDGE BAND ATTACHMENT MAY BE REPAIRED WITHOUT ELECTRICALLY TESTING

E AN/ASG-21, B-52H FIRE CONTROL SYSTEM RADOMES. THE WINDOW AREA IS DEFINED AS THE ENTIRE RADOME WITH EXCEPTION OF A 6-INCH WIDE BAND AROUND THE RADOME ATTACHING SURFACE. NO PATCHING IS ALLOWED IN THE WINDOW AREA. PATCHING IS ALLOWED OUTSIDE THE WINDOW AREA WITH THE FOLLOWING LIMITATIONS:

- MAXIMUM SIZE OF PATCH 4.00 INCHES IN DIAMETER
- MINIMUM SPACING BETWEEN PATCHES SHALL BE 6 INCHES

53450—4—2—12

Figure 30. Radome repair restrictions.

ings for communication, navigation, and radar equipment.

14-8. You will be inspecting and repairing laminated fiberglass, sometimes called solid wall type or solid laminate construction. This type of construction consists of layers of fiberglass cloth impregnated with resin, as shown in figure 28.

14-9. **Damage Evaluation.** Visually inspect the aircraft component or part for scratches, surface cuts, erosion, cracks, dents, holes, delaminations, and erosion of protective coating. A strong light placed behind the defective area is helpful in detecting certain types of damage. When you inspect a nose radome, carefully examine the interior surfaces for small delaminations under 1 inch in diameter. The spot delaminations or perforations (pinholes in inner and outer skins) are generally caused by electrical static discharges and can be identified by an area with a dark center or an evidence of burned resin.

14-10. To help you classify the damage, many manufacturers will include in the technical order a damage evaluation chart by which you can determine the types of damage and where to find the repair procedures. Chart 1 is typical of those you will find in many technical orders; it will give you the type allowable, reparable damage, and the paragraph number for repair procedures. Some manufacturers will also classify the damage as minor and major repair and give you procedures for each type. A minor repair can be considered a repair which can be made in a very short period of time, for example, see chart 1, column Type of Damage, and find Cracks. The next column, Allowable Damage, states "Not allowable," meaning the crack must be repaired. Column Reparable Damage states: "All cracks shall be repaired as follows: Damage less than ½ inch in length, damage greater than ½ inch in length." You can consider a minor repair to be a crack of less than ½ inch. A major repair a crack of more than ½ inch in length. The last column, Repair Paragraph, gives the paragraph number for repair procedures. Many manufacturers classify repairs as Class I, II, III, etc.

14-11. Most of your repairs will be on radomes. Repairs to a damaged radome are made to maintain the structural and electrical properties. There are many restrictions to determine whether the radome is to be repaired or replaced. To help you to evaluate the damages, many manufacturers will have drawings in the technical order for the specific aircraft (see figs. 29 and 30) showing you the critical areas and a criteria to be followed.

14-12. **Materials, Tools, and Equipment.** The pair of any laminate construction requires you to use the approved materials as given in the technical order for the specific aircraft. Only authorized substitutions are recommended. The resins to use for the specific repair (type of resin, promoter, catalyst, curing time) are given in the manufacturer's instructions and technical orders. The resins should be stored in closed metal containers in a cool place such as a refrigerator at approximately 40° Fahrenheit. Catalyst, promoters, and solvents are very reactive and are stored in the original containers, and isolated from one another. Store in a cool place. Other materials and equipment you will need are PVA film, cellophane tape, Duxseal or zinc chromate putty (paste) sealing compounds, safety goggles or face shield, rubber apron and gloves, cotton gloves, balance scales, cheesecloth, and clean rags.

14-13. Tools needed are scissors, spatula, knife, scribe, flexible straightedge, compass, squeegee or phenolic laminate material made of ⅛ or $^5/_{16}$ inch thickness, approximately 3 or 4 inches square, with a radius on one end. The squeegee or phenolic material is used to smooth out the repair and to remove air bubbles and excessive resin in the impregnated cloth layers before curing the repair.

14-14. Equipment you need is a vacuum pump with airhose or vacuum tubing. A vacuum pump which has a minimum vacuum pressure of about 20 hg (inches of mercury) is practical for all purposes. This method called vacuum bag pressure curing or vacuum bagging is used (1) to cure resin in the repair of laminate fiberglass parts, (2) to apply uniform pressure to the fiberglass surface, (3) to reveal and remove air bubbles and excess resin, and (4) to provide a void-free surface. PVA film is sealed over a repair and air is removed; this causes atmospheric pressure to push the plastic film against the repair. The technical order will give you the amount of psi needed on the repair. Figure 31 illustrates a vacuum bag on a repair. The following steps will describe the process of setting up this method to obtain a void-free laminate repair.

(1) Make ready your repair parts and install as instructed for that specific type of repair.

(2) Place a breather strip made of felt, ¼ inch thick and 1 inch wide, or a flexible coil spring (screen door spring) around the entire repair. Place it approximately 1 inch from the wet laminate.

(3) Lay a continuous strip of zinc chromate putty or Duxseal (roll in a rope form of approximately ½- to ¾-inch diameter) around the outside of the repair and outside of the coil spring or felt strip.

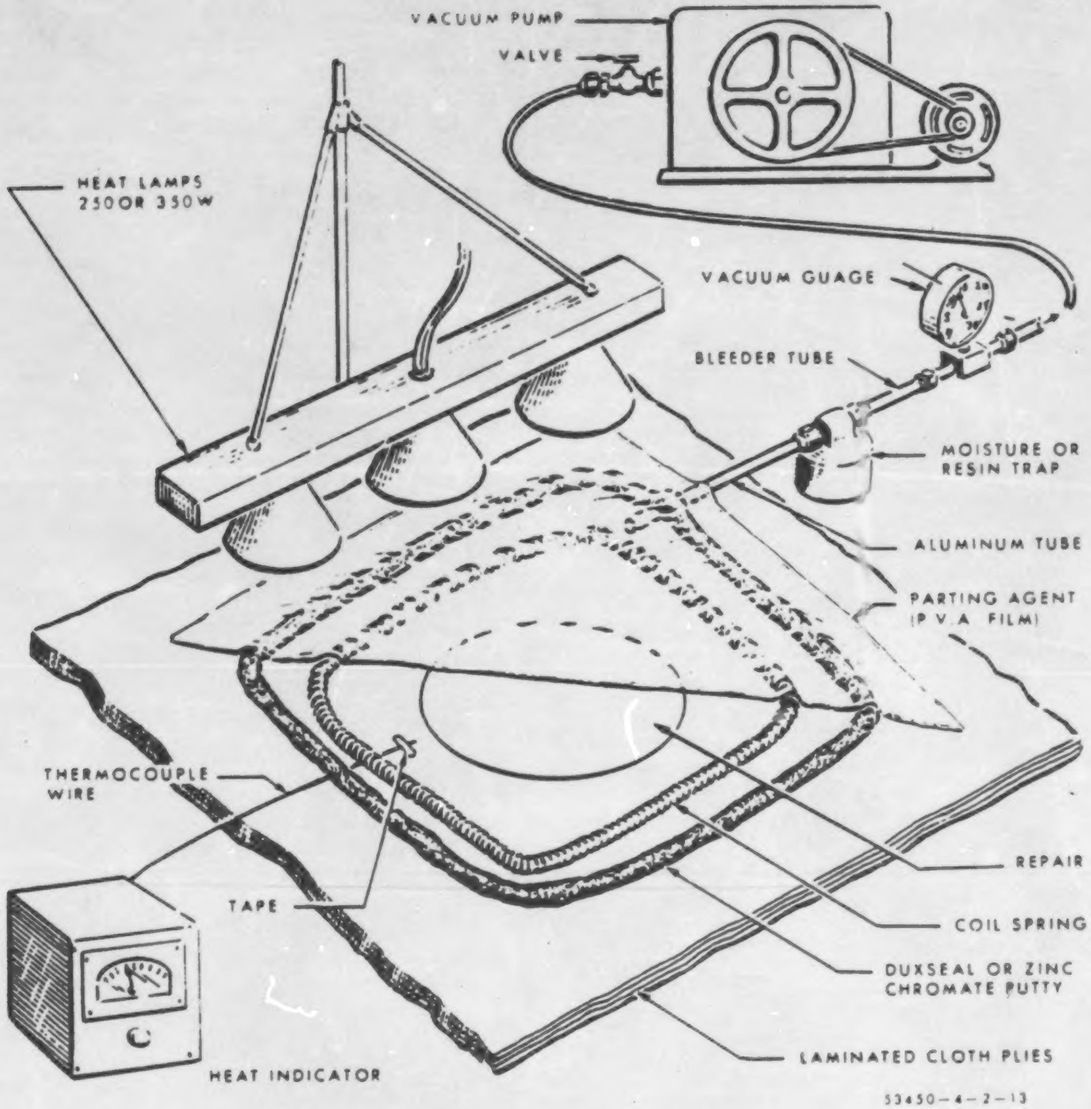

VACUUM PUMP
VALVE
HEAT LAMPS 250 OR 350 W
VACUUM GUAGE
BLEEDER TUBE
MOISTURE OR RESIN TRAP
ALUMINUM TUBE
PARTING AGENT (P.V.A. FILM)
THERMOCOUPLE WIRE
REPAIR
TAPE
COIL SPRING
DUXSEAL OR ZINC CHROMATE PUTTY
LAMINATED CLOTH PLIES
HEAT INDICATOR
53450—4—2—13

Figure 31. Vacuum bag pressure curing.

(4) Cut from a sheet of PVA film a piece to conform to the repair area and to extend approximately 1 inch beyond the strip of Duxseal or zinc chromate putty.

(5) Place the open end of the aluminum tubing (which is attached to the vacuum hose) beyond the Duxseal or zinc chromate putty to the edge of the spring or felt strip.

(6) Pack the putty around the tubing. When the vacuum line does not have a moisture or resin trap, you must place several layers of cheesecloth over the open end of the aluminum tubing. This will prevent resin, putty, or other foreign material from entering the vacuum line to the pump.

(7) When using heat to cure a repair, place a thermocouple wire (peel covering from wire approximately ½ inch from end) approximately ½ inch from wet laminate. Tape the wire to the surface with mylar or cellophane tape. Imbed the wire into the Duxseal or zinc chromate putty to prevent air leakage along the wire. Hook the thermocouple wire to a heat indicator such as a pyrometer or a potentiometer The heat indicator will have different heat ranges, for example, 0 to 400° or 1200° Fahrenheit.

(8) Place the PVA film over the repair (wet laminate) and press film into the Duxseal or zinc chromate putty.

(9) Apply vacuum slowly to the repair. The

PVA film will collapse or flatten over the repair area. Check for leaks around the putty. Stop any leakage of air to prevent loss of vacuum.

(10) Work out the wrinkles in PVA film with a squeegee or phenolic block. Using the radius end, wipe out all air bubbles and excess resin. Start approximately at the center and sweep toward the edge of repair. Use a slow motion to sweep out the bubbles along with the resin.

(11) When all air bubbles and excess resin are removed, stop: further wiping will create air or vapor voids. This will be indicated by a whitening or loss of transparency.

(12) If you puncture the film while wiping, repair with transparent tape. Remove all trapped air from the repair again by wiping the surface.

(13) Maintain the vacuum pressure until the repair is cured.

14-15. Infrared heat lamps are used to shorten the curing time of repairs. A single lamp will adequately cure a repair up to 6 inches in diameter. A large repair may require a battery of lamps to insure uniform curing of the repair area. The lamps are centered over the repair at a distance of about 30 inches. This will give a temperature of approximately 130° Fahrenheit, provided the surrounding areas are at room temperature of 70° Fahrenheit. Warmer or colder surrounding areas will require adjustment of the heat lamps. To accurately control heat to the repair, use a heat indicator with thermocouple wire. The temperatures for heat-curing repairs are contained in the applicable technical order.

14-16. **Repair Methods.** When making repairs, your main objective will be to equal as near as possible the strength and electrical properties of the original part. You will also want to keep the weight at a minimum. This you can accomplish by using approved materials and working techniques. Smoothness of the outside surfaces and maintaining uniformity in thickness of facings are very important. When you make deviations from the technical order, they can hinder the function of proper radio and radar reception and transmission. Repairs of punctured facings and delaminations will necessitate removal of damaged material and its replacement with approved materials, the same thickness as the original being carefully maintained.

14-17. After leaving a resident course you will train from 3 level to 5 level. Upon entering your new duty station you may have difficulty in the techniques and materials involved in repairing laminated fiberglass unless you have had actual experience in making repairs. Watch an experienced man and have him help you to make repair on an unusable part. All repairs made to aircraft parts or components are inspected by qualified personnel. They inspect for uniform thickness, void freeness, smoothness, and quality bonding of the fiberglass cloth and resin material. The repairs, techniques, and procedures given in this chapter are to help you to obtain your 5 level. The repairs are typical. When you are slated to make a repair on an aircraft component or part, be sure to use the technical order for the specific aircraft you are to repair.

14-18. Aircraft components and parts are generally removed from the aircraft to be worked on. Cleaning of the surface to be repaired is of primary importance to your success of making a good acceptable repair. An area that is contaminated with paint, grease, oil, wax, oxides, and other dirt do not take a good bond. Even a "clean" fingerprint will prevent a good bond because of the natural oils in the skin. When you are removing paint, exercise caution, because paint removers will dissolve adhesive if allowed to enter the damage area or in joints. To remove erosion-resistant coatings, consult the notes on uses of solvents and their application, which are given in the technical order for the specific aircraft.

14-19. Minor or Class I repairs, for example, scars, scratches, surface abrasions, or minor rain erosion not penetrating through the first ply facing or fiberglass cloth will be repaired as follows:

(1) Clean damaged area thoroughly and carefully, using a clean cloth saturated with methyl ethyl ketone (MEK), Specification TT-M-261.

(2) Lightly sand the damaged area using number 280 grit sandpaper. Clean the sanded area thoroughly using MEK. Make sure that moisture and solvents are completely removed to prevent their inhibiting the cure of the resin.

(3) Mix resin according to the applicable technical order and apply one or two coats of catalyzed resin to the abraded surface. Fill to level of surface.

(4) Cut a piece of cellophane or PVA film approximately 2 or 3 inches larger than the resin-coated surface and lay it on the repair area. The film will provide a smooth surface beneath which the resin can cure.

(5) Tape the film in place and work out all air bubbles and excessive resin. You can vacuum bag the area if you so desire. Cure the repair as given in the specific technical order.

(6) After the resin has cured, remove the film. Excess resin can be sanded to surface level.

(7) When a rain erosion coating is removed to accomplish a repair, replace in accordance with the technical order procedures.

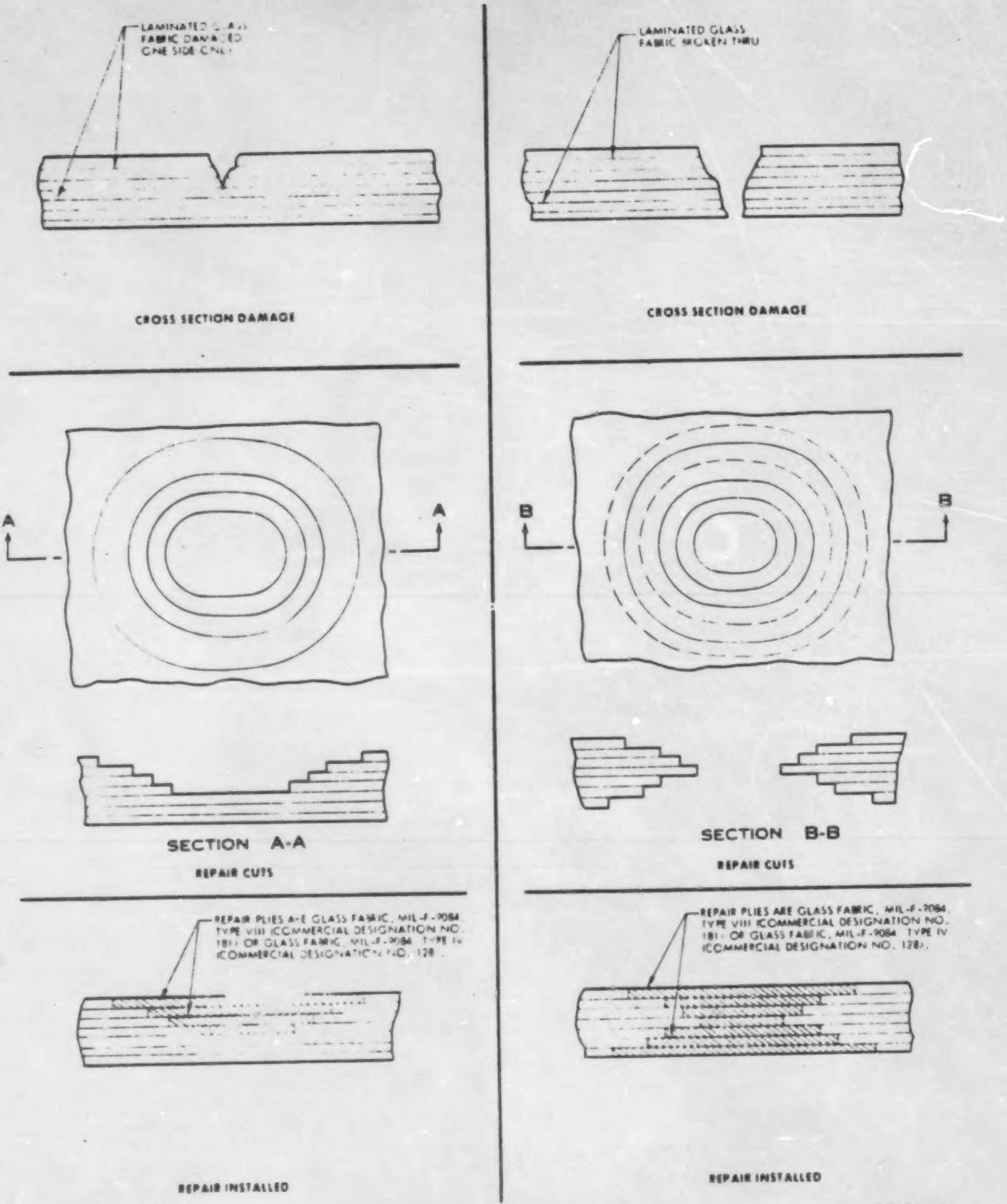

LAMINATED GLASS FABRIC DAMAGED ONE SIDE ONLY
CROSS SECTION DAMAGE
A
A
SECTION A-A
REPAIR CUTS
REPAIR PLIES ARE GLASS FABRIC, MIL-F-9084 TYPE VIII (COMMERCIAL DESIGNATION NO. 181) OR GLASS FABRIC, MIL-F-9084 TYPE IV (COMMERCIAL DESIGNATION NO. 128).
REPAIR INSTALLED
LAMINATED GLASS FABRIC BROKEN THRU
CROSS SECTION DAMAGE
B
B
SECTION B-B
REPAIR CUTS
REPAIR PLIES ARE GLASS FABRIC, MIL-F-9084 TYPE VIII (COMMERCIAL DESIGNATION NO. 181) OR GLASS FABRIC, MIL-F-9084 TYPE IV (COMMERCIAL DESIGNATION NO. 128).
REPAIR INSTALLED
53450-2-4-14

Figure 32. Step joint method.

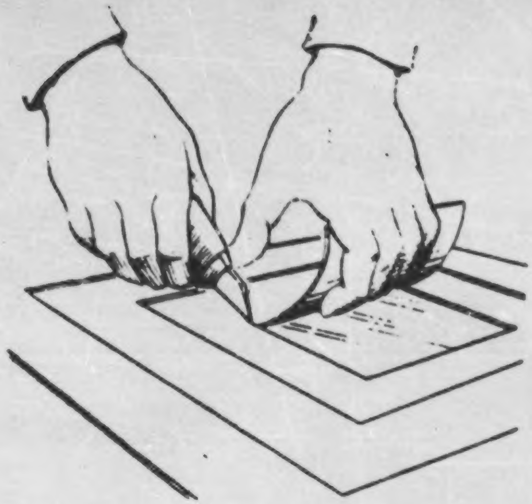


Figure 33. Removing damaged face plies, step joint method.

14-20. A repair to laminate fiberglass in which the cloth plies are damaged is considered a major repair: some manufacturers call it a Class II repair, etc. Damage through one or more plies or completely through the part will require you to remove the damaged portion and replace with approved materials in such a manner that normal stresses can be carried over the area. The preferred method for repairing the area is accomplished by the *step joint method* (see fig. 32).

(1) Outline the damage area to the shape of circle, square, or rectangle (round all corners of a square or rectangle).

(2) Count the number of damaged skin plies and subtract one ply. Multiply by 1 inch (four plies less one equals three plies time 1 inch equals 3 inches). Extend the side you have outlined around repair (3 inches).

(3) Use a sharp knife or specially prepared cutter and cut along the outer line. Cut through the first ply only. Do not cut into the second ply as it can weaken the repair.

(4) Remove the cut outer ply by inserting a knife or putty knife under a corner. Begin prying loose until it is removed.

(5) Scribe on the exposed ply a similar outline reducing the dimension 1 inch. Remove the ply as you did the first ply.

(6) Repeat the procedures until all damaged plies are removed (see fig. 33).

(7) Lightly sand exposed plies and clean surfaces with MEK. Be sure to thoroughly dry the surfaces.

14-21. Procedures for replacing layers or cloth plies vary from one manufacturer to another, but repairs are always made to preserve the structural and electrical qualities of the part. The procedures to be given are typical. Always consult the technical order for the specific aircraft.

(1) Cut replacement patches from glass cloth. The same thickness, warp, fill direction, and style of original material. Make them larger than the area they are to fit. Cut two pieces of cellophane or PVA film approximately 2 inches larger than the patches for each step.

(2) Examine figure 34 before attempting your repair. Starting with the smallest or innermost patch, impregnate the glass cloth with catalyzed resin—that is, 45 to 50 percent resin (weight of resin equal to weight or dry glass cloth). Place it between two sheets of cellophane or PVA film. Cut with scissors to the exact size you need for this step in the repair (see fig. 35). This method prevents the fraying of cloth edges. Templates can be made from cardboard to correct size for each step in the repair (see figs. 34 and 35).

(3) Fit the innermost patch (smallest) to the area. The pieces of fabric are laid in place by first removing the PVA film from one side of the fabric. Place the exposed fabric in position on the repair. Then remove the second piece of PVA film (see fig. 36). The edges are to be butted to the existing bond ply. Be sure the weave direction of replacement ply runs in the same direction as the existing plies or strength will be reduced.

(4) Place a sheet of cellophane or PVA film over the replacement ply. Work out all of the air bubbles with a squeegee or phenolic block. When the ply is void-free and smooth, cure in accordance with the manufacturer's instructions. When you find it difficult to obtain a void-free and smooth ply, vacuum bag the area.

(5) Lightly sand the cured repair ply surface. Now you can place the next cloth ply in the same manner as the first. Repeat the process until all steps have been placed.

14-22. When the repair has cured, lightly sand the surface as much as is necessary to obtain a smooth surface and to remove excess cured resin.

14-23. On solid laminates, when damage extends completely through all plies, remove one-half of the damaged face plies from one side and complete the replacement, then repeat the same procedures on the opposite side of the damaged area.

14-24. A skin *delamination* is a separation between two or more plies of fiberglass. Delamination is caused by improper bonding, the part being dropped, or the part being struck by a heavy object. Repair a skin delamination as follows:

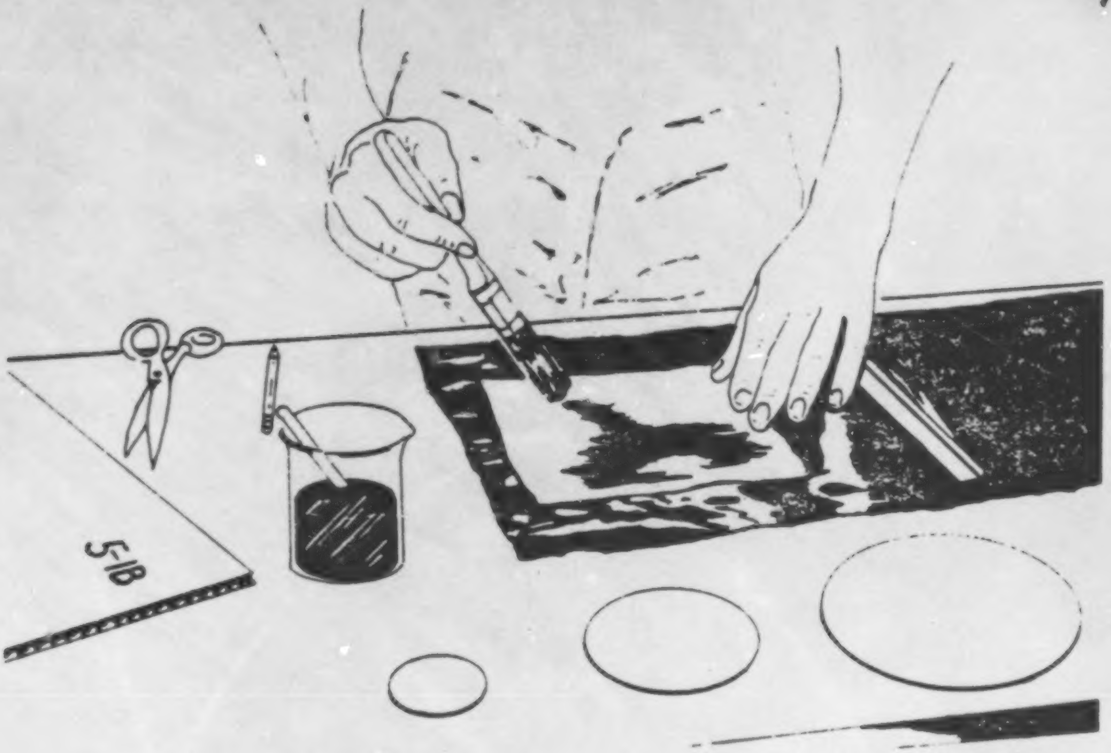

5-IB
53450 4 2 6

Figure 34. Brushing resin into glass fabric.

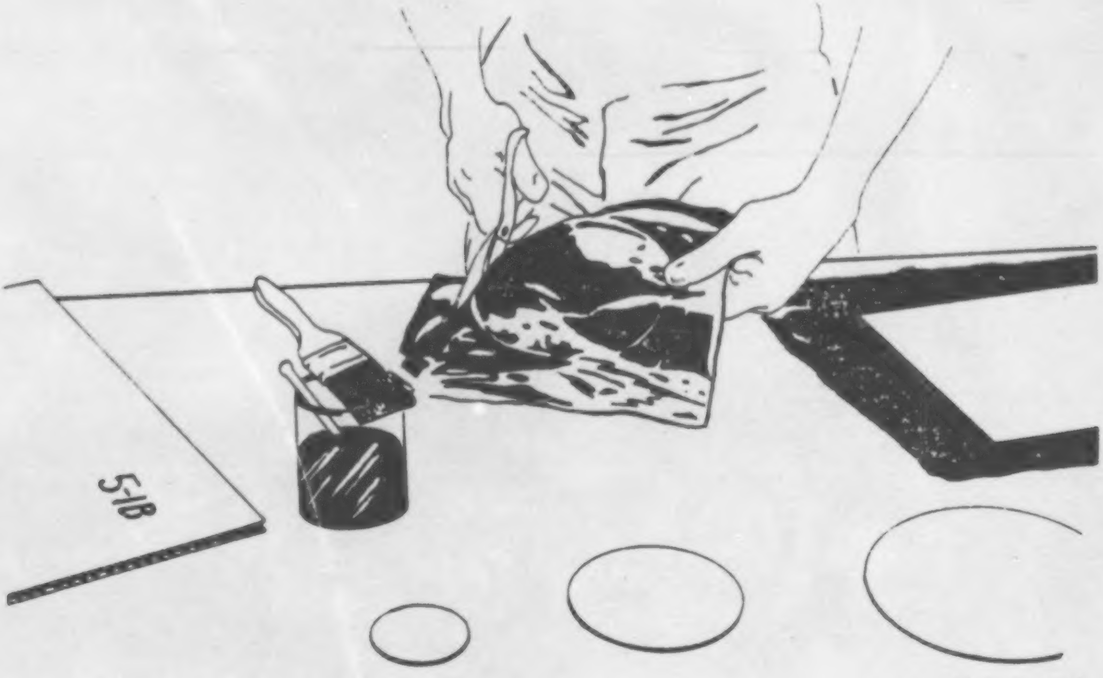

5-IB
53450 4 2 17

Figure 35. Cutting impregnated fabric between PVA film.

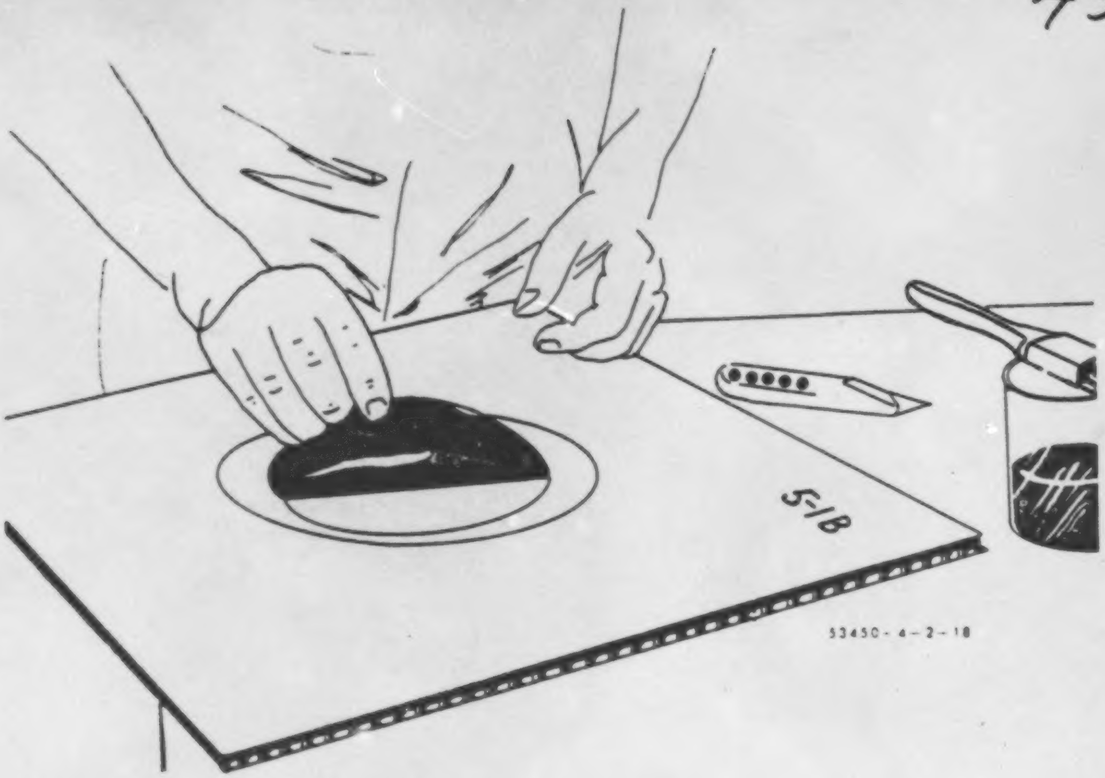


Figure 36. Removing PVA film.

(1) Drill a hole into the delamination area using a number 60 drill bit.

(2) Use a hypodermic syringe and needle and inject resin slowly into the delaminated area. When injecting resin and air entrapment occurs, drill additional holes. Inject resin until it flows freely from the drilled holes.

(3) After the void is completely filled, bring the delaminated area down to the proper thickness. Work out excess resin from between the layers of laminate. Cover with cellophane or PVA film.

(4) Apply pressure to the area using C-clamps or vacuum bag and cure according to the applicable technical order.

14-25. **Quality Inspection.** After a repair is completed by you, it is inspected for good workmanship. Repairs are inspected by shop personnel to insure compliance with the requirements of the technical order. The inspection consists only of a visual or metallic ring test. Minor defects are acceptable when they do not exceed specific specifications and are within the allowable limits.

a. The laminate must be within the tolerance of the drawings and specifications and of uniform workmanship.

b. Each layer or fabric shall butt up to the existing ply, unless otherwise specified, to form a continuous layer.

c. There shall be no cracks in the facing or ply repair.

d. Wrinkles are not allowed. They are defined as a raised fold of cloth in a ply and reduce tensile and compressive strength.

e. Holes that penetrate the first layer of glass cloth (ply) are not acceptable.

f. Blisters are areas in which there is a lack of bond between any two plies of glass cloth in a repaired laminate. Internal blisters or styrene bubbles less than 0.05-inch diameter are permitted in the two outer layers when they have a "wet out" appearance; however, blisters of ¼-inch diameter and smaller and 4 inches apart are allowed in the other layers.

g. Delamination is an unbonded area and not allowed if larger than the sizes and quantity specified in the applicable aircraft technical order or given in TO 1-1-24. Delaminated areas will have a whitish appearance through translucent plies. When the plies are not translucent, you can detect delamination by lightly tapping the surface with a blunt instrument or a 25-cent piece (tap lightly so as not to damage the part). The sound of the tapping will be a clear metallic ring over a well-bonded area and a dull thudding sound over a delaminated area. A large delaminated area is soft, flexible, or of balloon characteristic and can be detected by visual means or by the pressure of your thumb or hand on the suspected area.

h. Voids or pores extending into the glass cloth of the outer ply are not acceptable. Small pits are acceptable in the resin seal coat. Pitting on the outside of a radome surface is repaired as required. Laminates containing high percentages of voids tend to absorb moisture and affect the electrical characteristics of the radar system's operation.

i. No foreign matter or substances (metal particles, etc.) are allowed. They can cut down the effectiveness of the radar system.

j. In a good repair, the weave of the glass cloth is barely visible through the resin; when you cannot see the weave you have an excessive amount of resin. The excess resin can cause a degrading of a radar system.

k. Starved areas are not allowed. A starved area is one in which the glass cloth is not impregnated with resin.

l. The repair surface must be cured and free of tackiness (softness). A Barcol impressor is used to test the surface for hardness. A properly cured repair must have a minimum average Barcol hardness of 55. On large parts, take an average reading from ten tests. On small parts, an average drived from five readings is sufficient. Do not take Barcol readings on surfaces where the skin is less than 0.01 inch thick.

14-26. Figure 37 illustrates a hardness tester. To operate the tester, exert light pressure against the instrument to drive the spring-loaded indenter into the material to be tested. The instrument can be used in any position. The reading is indicated on the dial. The dial is divided into one hundred graduations.

14-27. Airframe personnel are not qualified to perform all of the necessary testing that may be required to insure that a repaired radome will function properly. The type of electrical test required after a repair is completed depends on the purpose for which the radome was designed. Facilities and qualified personnel to perform the test are not usually available in an airframe repair shop. Electrical tests will be controlled by certified personnel from the proper organization when their services are necessary for insuring a satisfactory repair. Electrical testing is performed before radomes are placed in service. The purpose of electrical testing is to insure proper transmission of electronic signals.

14-28. After a repair is completed, the final step is to apply a finish to the part or enclosure (rain erosion coating, etc.) identical to the original finish. The type of protective coating for fiberglass facing must be in accordance with requirements of the applicable aircraft technical order or TO 1-1-24.

14-29. The frontal areas of all fiberglass enclosures (radomes) are exposed to considerable erosive action when the aircraft is flying at high speeds through rainstorms. If unprotected, these area become covered with fine pits. The pits develop into small eroded areas and actually delaminate the glass fabric facings if the erosion is allowed to progress unchecked. Rain erosion coatings conforming to military specifications (contained in the applicable aircraft technical order or TO 1-1-24) have been found to retard this eroding action. These materials will protect the fiberglass surface indefinitely. The protective coating can be repaired and replaced when inspection indicates such work is necessary. It has been found that the coatings perform their function much better when the fiberglass surface is smooth (not glossy) and free of all small voids.

14-30. To prepare the surface for these protective coatings, the glossy surfaces must be lightly sanded. Use a fine grade of sandpaper and uniformly scratch the surface. Remove

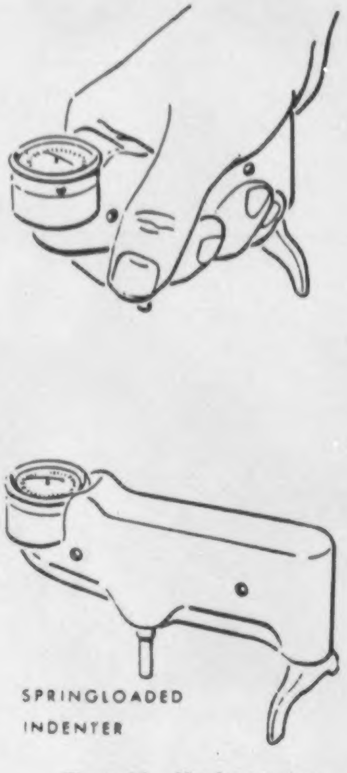


Figure 37. Hardness tester.

sanding dust with a clean dampened cloth (toluol, MEK). Plastic parts to be given a coating should be done in an area that is free from dust and weather conditions. Best results are obtained when the coatings are applied at relative humidities below 60 percent.

14-31. **Safety Precautions.** General precautions to be followed in the shop are the same as those precautions stated earlier while working with mat molded fiberglass.

15. Honeycomb Core

15-1. The protective dome or fiberglass enclosures on our aircraft are coverings for radar equipment and radar antennas. They are called radomes. The fiberglass enclosures must be able to withstand the effects of hail, icing, rain, wind temperature and static changes, supersonic speeds, and stratospheric altitudes.

15-2. **Construction Features.** Fiberglass enclosures and parts consist of a fiberglass honeycomb core to which face plies of laminated glass cloth are bonded. The composition structure has proven very satisfactory because of its excellent dielectric qualities, strength, and resistance to weather erosion, etc. The core is used to separate the outer layers, or facings, to obtain a panel of high bending stiffness and to support the facings. The core keeps the facings elastically stable when highly stressed. This construction makes strong rigid parts with minimum weight.

15-3. By varying the sheet material, sheet thickness, cell size, and cell shape, cores of a wide range in density and properties can be produced. Most cores available are of hexagonal, sine wave, or square cells, as shown in figure 38. Requirements of greater importance than strength properties normally dictate the choice of core materials for radio and radar enclosures. Properties such as the dielectric constant, the loss tangent, and an exceedingly low rate of moisture absorption are of greatest importance. Strength is of great importance for large enclosures.

15-4. The core material in fiberglass enclosures will be of the type and thickness as specified in the applicable design drawing. One of the most common core materials in fiberglass enclosures is made of glass cloth impregnated with a polyester or a combination of nylon and phenolic resin. Honeycomb core cell sizes, (determined by the diameter of a circle inscribed in a cell) range from 1/16- to 3/8-inch diameter (usually in multiples of 1/16 inch). Honeycomb material is normally fabricated in blocks that can be cut on a band saw to the desired size (see fig. 39) or can be procured precut to the proper thickness.

15-5. The honeycomb cores fabricated from nonmetallic materials have very good thermal insulation characteristics. In considering thermal effects on fiberglass honeycomb, keep in mind that it acts as a reflective heat insulator. Glass fabric honeycomb has sufficient thermal insulation qualities to satisfy the requirements of the B-58 supersonic bomber.

15-6. Strength of the honeycomb depends on the cells maintaining their shape and position to support the skins which carry the major applied loads.

15-7. **Damage Evaluation.** Inspection procedures for honeycomb fiberglass enclosures and parts are the same as laminated fiberglass enclosures and parts. Surface damage to the face plies and core can be detected by visual inspection. When inspecting the core material, place the enclosure or part between yourself and a strong source of light. The translucency of the part will permit you to observe any defects in the core material. An ideal core bond will be observed as a substantial fillet of resin at each core skin interface. The absence of a fillet is not conclusive evidence of an inadequate bond. However, its absence will require you to further check the area. When you notice the resin fillet is missing, check the area, using the metallic ring test.

15-8. To help you inspect a damage, the following list defines terms which are most used. The illustrations in figure 40 also define damages.

a. Perforations—holes punched through all plies of fiberglass facing.

b. Delamination—separation of two or more fiberglass plies caused by improper bonding, part being dropped, or struck by heavy object.

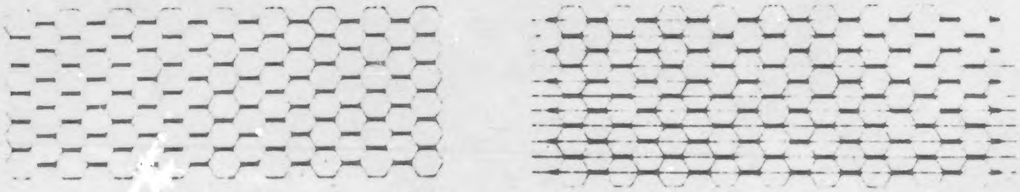
c. Separation of fiberglass facing from honeycomb core—caused by improper bonding, part being dropped, part being struck by heavy object, or water freezing in honeycomb core.

d. Core damage—damage to honeycomb core caused by an object piercing the face plies and core or crushing of panel.

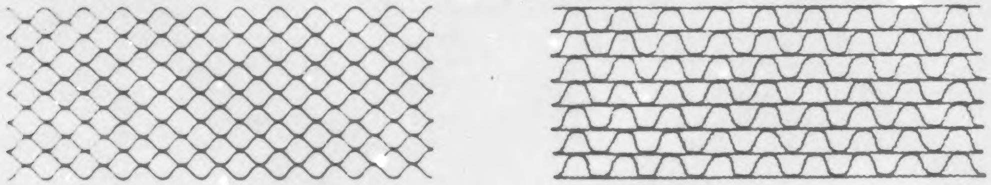
e. Small spot or electrical discharge—small hole through inner and outer facing and honeycomb core caused by discharge of static electricity. This type is found mainly in radomes.

15-9. Fiberglass enclosures (radomes) are susceptible to moisture and oil contamination. Moisture and oil can cause serious degrading of the performance of the aircraft's radar system. Contamination also causes weakening of the radome facing and the facing to core bond strength. Moisture detection is accomplished with the use of a radome moisture register (indicator). To determine the degree of moisture contamination, the moisture indicator is used as follows:

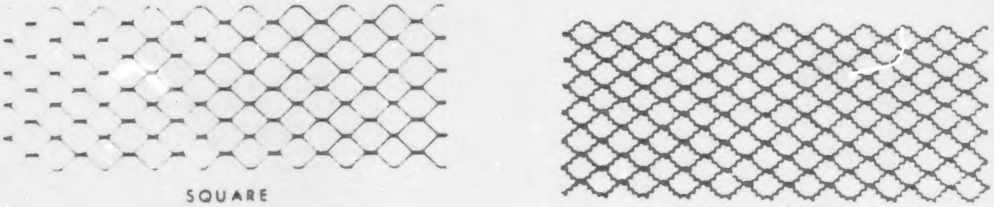
a. The indicator pointer is adjusted to zero position.


HEXAGON

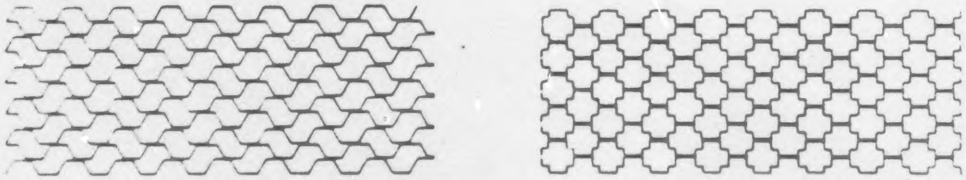
REINFORCED HEXAGON


SINE WAVE

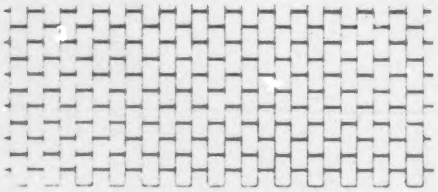
MULTIWAVE OR DOUBLE—CORRUGATED


SQUARE

CORRUGATED SQUARE


STAGGERED HEXAGON

CRUCIFORM


RECTANGULAR

53450 4-2-20

Figure 38. Honeycomb core cell configuration.

b. The electrode contact buttons must be cleaned. Dirty contacts will cause erratic readings.

c. The meter pointer is adjusted exactly over the red line, with power off.

d. Remove all surface moisture from the radome. Take readings over entire surface of radome at 6-inch intervals. Never take readings within 3 inches of metal edges and microwave absorbing material or when surface temperature of radome exceeds 100 Fahrenheit. The moisture content as read on the moisture indicator numerical scale shall not exceed the following limits:

- Radomes tested in the field, with or without erosion-resistant and antistatic coatings, must have a moisture reading less than 15.
- Antistatic coated radomes must be tested from the inside surface.

15-10. Oil and other contaminants beside moisture are removed by removing and replacing the entire affected area. A slight oil discoloration of core is not cause for core replacement. Core material that is noticeably dark in color because of oil saturation should be replaced during depot level repair.

15-11. Radomes are inspected for moisture or oil contamination prior to repairing or identifying as serviceable.

15-12. A list of equipment and procedures for detecting and removing moisture and oil from within the radome structure are contained in TO 1-1-24, *Maintenance, Repair, and Electrical Requirements of Fiber Laminate and Sandwich Constructed Radomes, all Aircraft.*

15-13. "Damage evaluation charts" are usually found in the -3 technical order for the specific aircraft. Different aircraft have different limitations as to damage that is reparable or nonreparable.

15-14. *Field repair restrictions.* Many manufacturers have limitations on repairs that can be made in the field. The specific technical order contains limitations for radomes. The critical areas and a criteria (see figs. 29 and 30) are examples found in many technical orders. A radome requiring an electrical test after a repair is sent to a depot for repairs.

15-15. *Handling precautions.* Caution should always be exercised whenever you handle fiberglass enclosures and parts. Do not place such components on rough surfaces and among metal parts. Avoid damages that result from dropping and dragging radomes on the floor, ground, striking them with tools, and hauling them on unpadded carts. The enclosures must be placed on padded dollies or padded racks.

15-16. **Materials, Tools, and Equipment.** The materials, tools, and equipment to be used for fiberglass honeycomb repairs are the same as laminated fiberglass repairs—with one exception

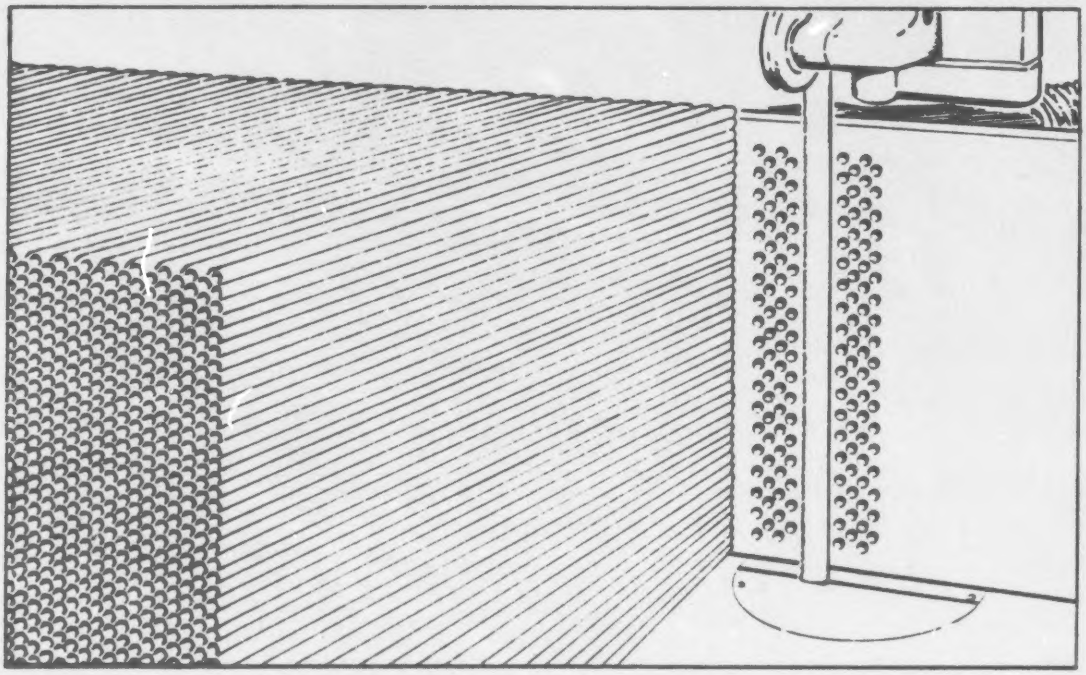


Figure 39. Honeycomb core material.

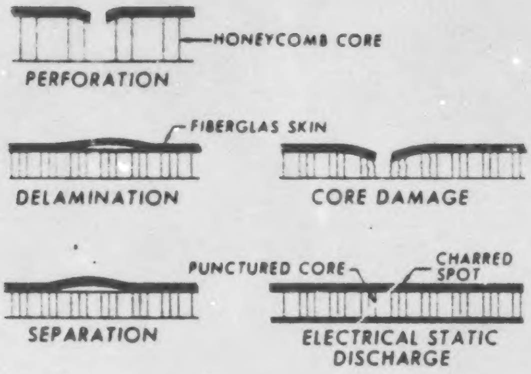


Figure 40. Definition of damage terms.

—the honeycomb core material. We have already mentioned the core material and we shall discuss additional information in later paragraphs.

15-17. The repair of any sandwich constructed fiberglass enclosure and parts (radome) requires the use of approved materials for repairing the damaged portion. Duplication of original materials or authorized substitutions as specified on the latest drawing or specification of the plastic part is recommended in all cases.

15-18. The facings of enclosures and parts (radome) are made of layers of fiberglass cloth impregnated and bonded together with polyester or epoxy resin. In all repairs it is important to determine the direction of the threads in the original facings so that the direction of the threads in the replacement layers can be made to match in each ply.

15-19. The fiberglass cloth used in the repair of radomes must be as specified in Specification MIL-C-9084 with the same gage as the original ply.

15-20. The core material selected for the repair of radomes depends on the type of original core in the repair area. The principal controlling dimension is the molded core thickness, density, and cell size shown on the applicable manufacturing drawings or specifications. Core direction of the replacement honeycomb should be in the same direction as that removed so as to maintain uniformity. Figure 41 illustrates core direction (ribbon direction).

15-21. Replacement honeycomb core sections may be installed by either one of two methods: "flush fitting" or "interlocking." The method used should be the same as that employed in the original fabrication of the item. Procedures to be used for installation by either method are found in TO 1-1-24.

15-22. Specifications for radomes allow a large section of approved resins for use in the repair of radomes. Normally they will be of the polyester type, Qualified Products List (QPL) 7575, Specification MIL-F-7575. An epoxy resin MIL-F-9300A may sometimes be used. Radome detail specifications may determine the type of resin to be used for a particular repair. Basic resin formulations (type of resin, promoter, catalysts, curing time, etc.) will be as described in the resin manufacturer's instruction sheet unless different from the radome manufacturer's process specification, in which case the latter takes precedence.

15-23. Because you are working with resins, catalysts, promoters, and the solvents such as acetone (necessary to clean equipment), you must comply with local safety regulations as to fire and health hazards. The resins should be stored in a closed metal container in a cool place such as a refrigerator at approximately 40° Fahrenheit. Catalysts, promoters, and solvents are very reactive and should be stored in the original tight containers isolated from one another in a cool place.

CAUTION: *Never mix the catalyst and promoter together as they are explosively reactive as a mixture. Always mix the promoter with the resin first and then add the catalyst to the mixture. Do not inhale the fumes during mixing. Do not store catalyzed resin in an airtight container or an unvented refrigerator. Catalyze only enough resin for immediate use.*

15-24. **Repair Methods.** Repair procedures are developed with the objective of equaling, as nearly as possible, the strength of the original part with a minimum increase in weight, change of aerodynamic characteristics, and changing the electrical properties. This can only be accomplished by replacing damaged material with identical material or an approved substitute. Smoothness of the outside surfaces of high-speed aircraft is a necessity for proper performance, and consequently patches that project above the original surface must be avoided if at all possible. When this is impossible, the edges of the outer ply must

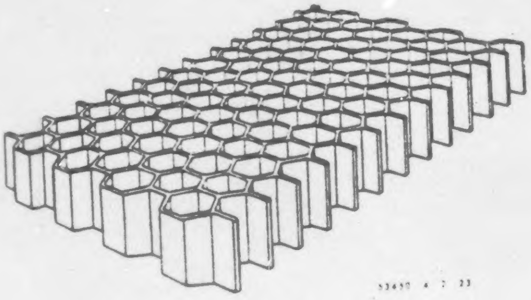


Figure 41. Reference axes for honeycomb cores.

be tapered to blend in with the original contour. Uniformity of thickness of core and facings is exceedingly important in the repair of the critical areas in fiberglass enclosures (radomes). Repairs of punctured facings and fractured cores in these areas, as we have often pointed out, necessitate removal of all the damaged material. The next step is the replacement with new material of the same type—that is, of the same thickness and of the same resin mixture as the original.

15-25. Repairs given in this course are field repairs. We recommend you select the applicable technical order for the specific aircraft to make any repair on aircraft enclosures. The repair techniques given are simple; even so, we know that personnel who have little or no experience with the materials and techniques involved in making repairs to fiberglass enclosures and parts may have difficulty in immediately interpreting the procedures and in making acceptable repairs during their first attempt. It is recommended that inexperienced personnel practice on unserviceable parts and be certified on each type of repair prior to working on serviceable aircraft. Fiberglass enclosures (radome) and parts usually are removed from the aircraft for repair; however, repairs to erosion-resistant coatings and Class I damage can be made without removing the part from the aircraft. Removal and application of rain-erosion coatings must be in accordance with the applicable aircraft technical order procedures.

15-26. The area to be repaired and approximately 4 inches adjacent to damaged area must be carefully cleaned. Use a clean cloth saturated with MEK or other approved cleaning agent. When there is paint on the surface, remove by sanding the area. Extreme care must be taken during sanding operations to avoid further damage to the plastic facings of the enclosures and parts.

15-27. Moisture detection and removal procedures are always made on enclosures (radomes) prior to accomplishing Class II and Class III repairs. Moisture and other contamination seriously affect the electrical properties of plastic enclosures; therefore, they must be clean and dry prior to electrical testing.

15-28. Plastic enclosures require repairs for damages other than those that can be seen visually. Enclosures that have poor electrical qualities or show evidence of many field repairs should be electrically tested prior to repair in an overhaul shop (depot). The objective of the pretest is to determine the electrical condition of the enclosure prior to repair.

15-29. The electrical test personnel will outline, with a grease pencil, the areas that do not pass the electrical test. The outlined areas must be repaired by replacing the material.

15-30. Damages to enclosures are divided into groups or classes according to the severity, possible effect upon the structure of the aircraft, and upon electrical efficiency. Each manufacturer has a different method of grouping and classing the repairs. To give you repairs that are more readily understandable, we have classified the damages into three basic classes. Repairs for Classes I, II, and III are discussed in the following paragraphs.

15-31. A Class I repair is a scar, scratch, surface abrasion, or minor rain erosion not penetrating through the first facing. The repair for these damages is the same as given for laminate fiberglass enclosures.

15-32. Class II repair consists of a damage extending through two plies of the plastic facing or completely through one facing of the enclosure and possibly into the core. To repair a damaged facing, use the step joint method (same as fiberglass laminate repair). For damage to one facing and core, use the step joint repair for the facing, with one exception: allow a minimum of one-half inch between the edge of the innermost ply and the periphery of the core material that is to be removed (see fig. 42). After thoroughly cleaning the repair area with MEK, cut a piece of core material to the exact size of the damaged area. The thickness and cell size must be to the manufacturer's specifications, as given in the applicable aircraft technical order.

15-33. When cutting of the honeycomb is required, a band saw is the most convenient equipment to use. The blade should have about 32 teeth per inch and a speed of about 5000 feet per minute. Slight variations in the blades or speeds may be necessary for particular cell sizes and densities. The optimum cutting conditions can probably best be achieved by trial and error

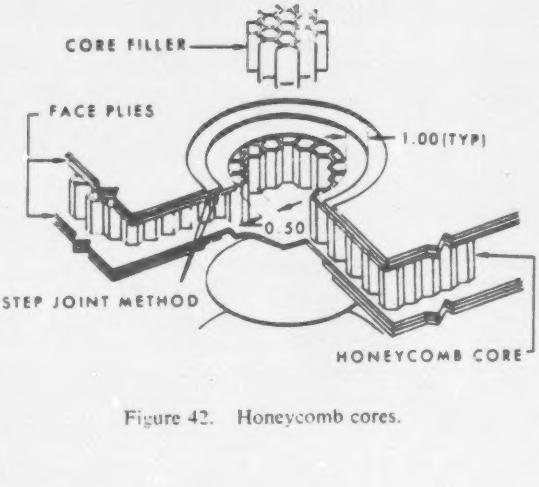
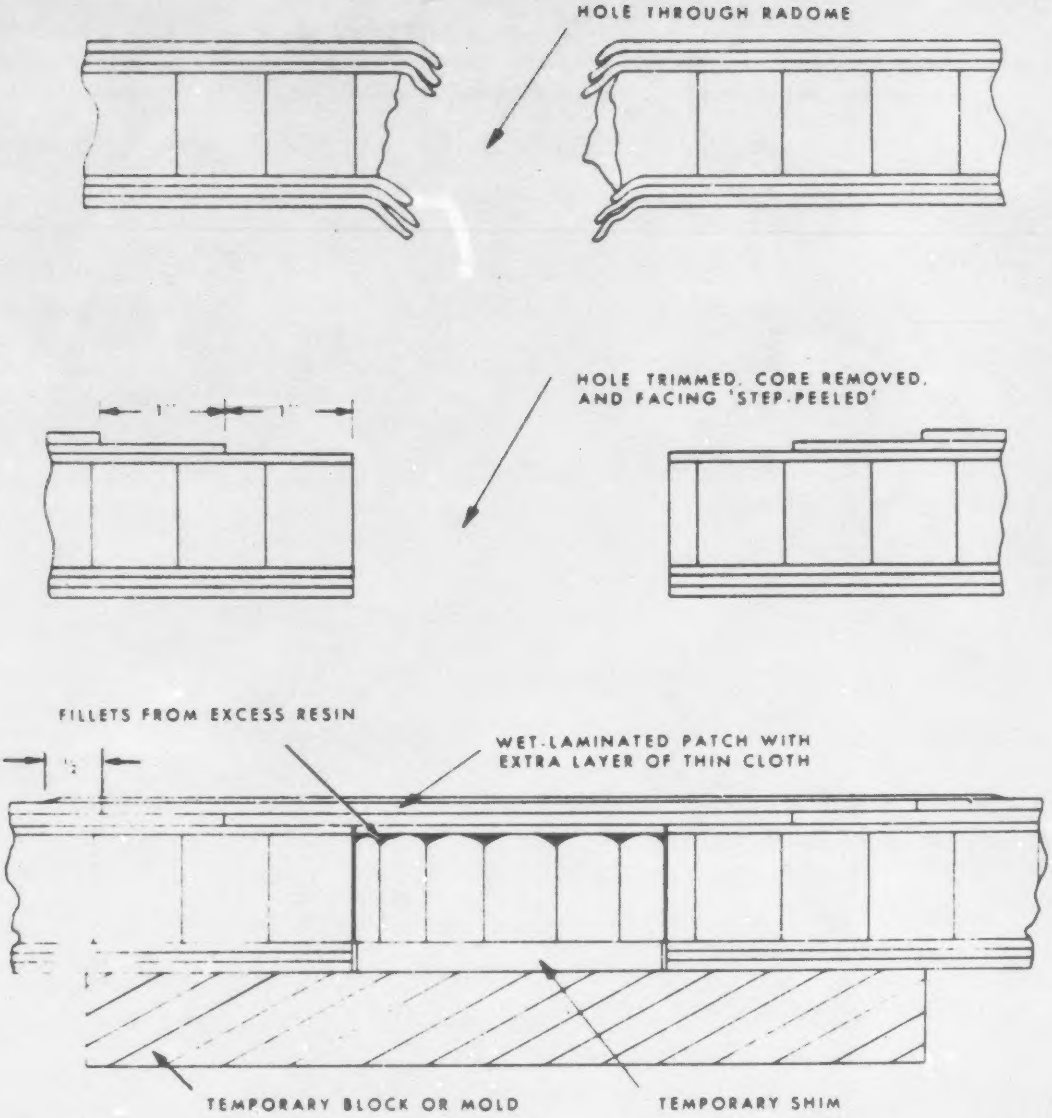


Figure 42. Honeycomb cores.


HOLE THROUGH RADOME
HOLE TRIMMED, CORE REMOVED, AND FACING 'STEP-PEELED'
1"
1"
FILLETS FROM EXCESS RESIN
WET-LAMINATED PATCH WITH EXTRA LAYER OF THIN CLOTH
½
TEMPORARY BLOCK OR MOLD
TEMPORARY SHIM

COMPLETE BY STEP-PEELING AND WET-LAMINATING OPPOSITE FACING IN A SIMILAR OPERATION

Figure 43. Details of step joint method of repair of Class III damage.

for the specific application. After the area is thoroughly clean and dry, apply one coat of catalyzed resin to the cutout (honeycomb) area on the enclosure facing and a like amount on all mating surfaces of the replacement core. Then insert the core material with core cells that run in the same direction as the existing core. Make sure that the replacement core conforms closely to the existing undamaged honeycomb core. Insert the first impregnated ply over the core material. Place PVA film over the ply and apply light uniform pressure by means of tape, sand, or vacuum bags. Keep excess resin from entering the core cells, as this could hinder radar efficiency. Cure the repair by heat lamps or by inserting the entire part in an air circulating oven at temperatures in accordance with the resin manufacturer's instructions. Complete the repair (same as for laminate enclosures) as instructed by the applicable technical order.

15-34. Class III repair is made to fiberglass enclosures and parts on which both facings and core have been damaged. The repair is made by removing and replacing the damaged face

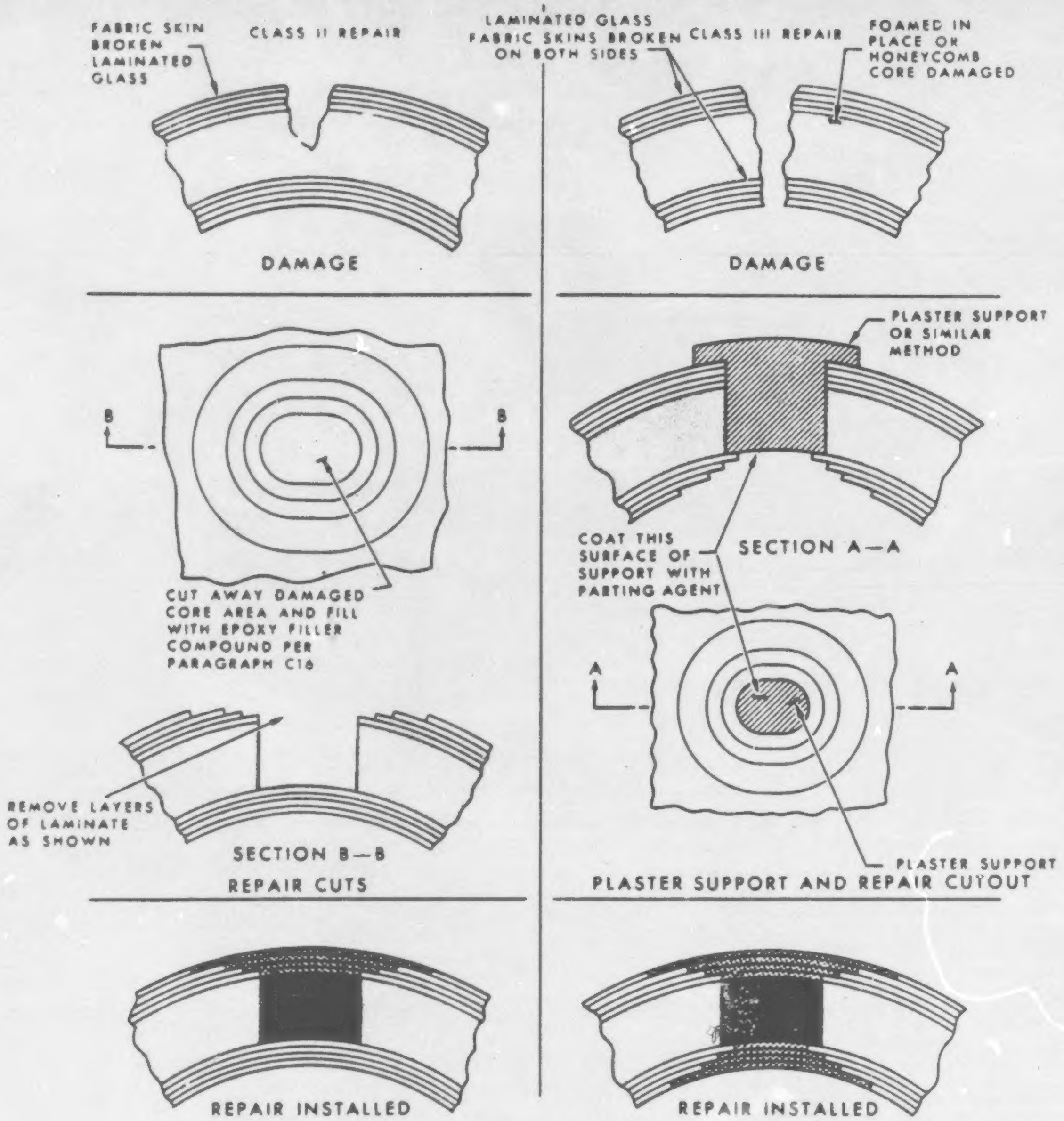

FABRIC SKIN BROKEN LAMINATED GLASS
CLASS II REPAIR
LAMINATED GLASS FABRIC SKINS BROKEN ON BOTH SIDES
CLASS III REPAIR
FOAMED IN PLACE OR HONEYCOMB CORE DAMAGED
DAMAGE
DAMAGE
PLASTER SUPPORT OR SIMILAR METHOD
B
B
CUT AWAY DAMAGED CORE AREA AND FILL WITH EPOXY FILLER COMPOUND PER PARAGRAPH C16
COAT THIS SURFACE OF SUPPORT WITH PARTING AGENT
SECTION A—A
A
A
REMOVE LAYERS OF LAMINATE AS SHOWN
SECTION B—B
REPAIR CUTS
PLASTER SUPPORT
PLASTER SUPPORT AND REPAIR CUTOUT
REPAIR INSTALLED
REPAIR INSTALLED

Figure 44. Typical repair for glass fabric reinforced plastic parts.

plies and core material as previously outlined for Class II repair. Never remove inner and outer fiberglass enclosure face plies at the same time. One facing must be completed before a repair is made on the opposite facing.

15-35. To accomplish a Class III repair, you must provide the opposite side of the sandwich material with a temporary mold or block to hold the core in place during the first face ply buildup. You can use a shim simulating the thickness of the opposite side facing and secure it in place by means of clamping, propping, or lashing. After molds or shims have been temporarily secured in place, the damage area is ready for rebuilding. Study figure 43 for details in the step joint repair. The replacement core is coated with catalyzed resin on all sides (edges) and the top surface, leaving the bottom surface (next to the shim) uncoated. Insert the core in place on the repair. The glass fabric sheets (patches) are now ready to be impregnated with resin, cut to correct size, and placed in the repair, the smallest patch being laid over the replaced core. Complete the repair as you did for Class II repair.

15-36. Remove the mold or shim and repeat the removal and replacement of facing. There is one exception: make the cutout ply area approximately 2 inches larger than the first ply cutout area on the opposite face repair. This prevents the joints of the inner and outer repair area from being in the same position. Study figure 44. It shows you a typical repair of both facings. Cure the repair according to the manufacturer's instructions for the resin used. The contour of the enclosure must be retained throughout the repair. Never sand radomes to obtain the desired contour or to remove wrinkles. Finish the completed repairs as instructed by the applicable aircraft technical order.

15-37. Another method for removing damaged face plies is called the scarf method. This method is very seldom used and is not recommended when the damage extends into the core material. The scarf method can be used when the face plies are very thin or when repair damage removal (area) is less than 3 inches diameter. Consult TO 1-1-24 for detailed information on the scarf method removal.

15-38. Punctures of the skin where less than one cell size area is involved can be repaired by making a thick paste of resin mix and milled glass fibers. Work the resin mix with glass fibers into the puncture. Take extreme care to prevent excess resin from being injected into the core cells. When excess resin enters the cells, remove with a hypodermic syringe and needle. Vacuum bag the repair. Sweep out excess resin and entrapped air. Cure repair according to instructions contained in the applicable aircraft technical order.

15-39. Small separations or delaminations (sizes determined by repair restrictions in the applicable aircraft technical order) can be repaired by injecting (using hypodermic syringe and needle) a small amount of resin into the damage area. Apply pressure with C-clamps or vacuum bag, and cure according to the instructions contained in the applicable aircraft technical order. Repair is the same as that used for laminated skin delamination.

15-40. **Quality Inspection.** After completing the repair, you must inspect it for good workmanship. Inspection of the facings is the same as that mentioned for laminated fiberglass enclosures. A hardness test must be taken of the surfaces. The use of the hardness tester was mentioned in earlier paragraphs. In addition to the previous information given on the use of the hardness tester, the following is important when you test honeycomb sandwich structures:

a. The impressor's point should be placed over the supporting cell wall to obtain truer readings and also to avoid damage to face ply.

b. Low readings can be noticed when the point is placed over an open cell, which is due to the flexing of the face ply. Honeycomb cells are also checked for delamination between core and facing. The cores are inspected to see that the cells are not filled with resin. Filled cells will appear as shadows on the skin. Most manufacturers allow 1 percent of the cores to be filled before they are rejected. The first row of cells away from the edge band may be completely filled with resin without cause for rejection of the part. All final inspections of aircraft fiberglass enclosures and parts are contained in the technical orders for each assembly.

15-41. **Safety Precautions.** The general safety precautions to be followed when you are working on fiberglass enclosures and parts are the same as those for mat molded fiberglass.

16. Fluted Core

16-1. Some aircraft require the use of a hot air deicing type radome. This type of sandwich is constructed similarly to other plastic sandwich radomes with one exception: it has a series of specially designed glass cloth laminated flutes on a foam core casing. The flutes are placed in the longitudinal direction and interconnected to a hot air inlet and outlet. This allows hot air to circulate through the ducts (flutes). The entire radome can then be subjected to a certain degree of heat.

16-2. **Construction Features.** Some radomes are of three-layer and five-layer construction. The upper portion of the radome consists of three layers: (1) an outer facing, (2) a structural core, and (3) an inner layer of fiberglass plies. The lower portion of the radome consists of five layers: (1) an outer facing, (2) anti-icing ducts, (3) middle membrane (fiberglass plies), (4) structural core (honeycomb or foam core), and (5) the inner facing. Figure 45 illustrates three types of radome construction.

16-3. **Damage Evaluation.** To inspect and determine the extent of damage to fluted core radomes, use the same methods you used for laminated fiberglass and honeycomb core radomes. Check to make sure the middle membrane is undamaged. Undetected damage to the membrane will permit a pressure leak from the duct through the structural core to the inner facing. This can result in hidden interior delamination.

16-4. **Material, Tools, and Equipment.** The tools and equipment to be used to repair fluted core radomes are the same as those used for re-

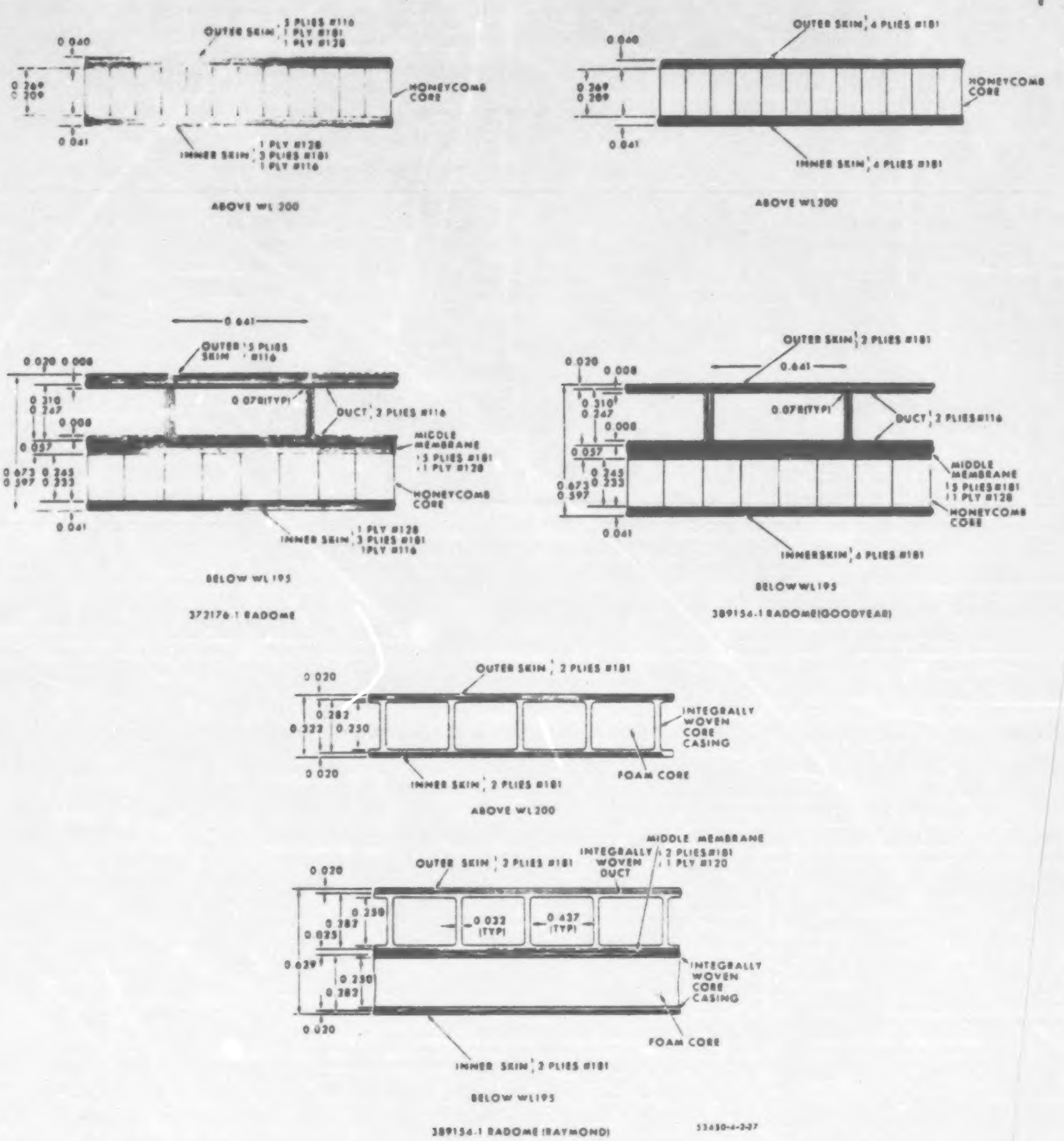

0 040
OUTER SKIN ; 3 PLIES #116
1 PLY #181
1 PLY #128
0 269
0 209
HONEYCOMB CORE
0 041
INNER SKIN ; 1 PLY #128
3 PLIES #181
1 PLY #116
ABOVE WL 200
0 040
OUTER SKIN ; 4 PLIES #181
0 269
0 209
HONEYCOMB CORE
0 041
INNER SKIN ; 4 PLIES #181
ABOVE WL200
0 641
OUTER SKIN ; 5 PLIES #116
0 020 0 008
0 310
0 267
0 078(TYP)
DUCT ; 2 PLIES #116
0 008
0 057
MIDDLE MEMBRANE ; 3 PLIES #181 ; 1 PLY #128
0 673 0 245
0 597 0 233
HONEYCOMB CORE
0 041
INNER SKIN ; 1 PLY #128
3 PLIES #181
1PLY #116
BELOW WL195
372176-1 RADOME
OUTER SKIN ; 2 PLIES #181
0 020
0 008
0.641
0 310
0 267
0 078(TYP)
DUCT ; 2 PLIES#116
0 008
0 057
0 245
0 233
0 673
0 597
MIDDLE MEMBRANE
5 PLIES#181
1 PLY #128
HONEYCOMB CORE
0 041
INNERSKIN ; 4 PLIES #181
BELOWWL195
389154-1 RADOME(GOODYEAR)
0 020
OUTER SKIN ; 2 PLIES #181
0 282
0 322 0 250
INTEGRALLY WOVEN CORE CASING
0 020
INNER SKIN ; 2 PLIES #181
FOAM CORE
ABOVE WL200
MIDDLE MEMBRANE
INTEGRALLY WOVEN DUCT
2 PLIES#181
1 PLY #120
0 020
OUTER SKIN ; 2 PLIES #181
0 250
0 282
0 025
0 032 (TYP)
0 437 (TYP)
0 629
0 250
0 282
INTEGRALLY WOVEN CORE CASING
0 020
FOAM CORE
INNER SKIN ; 2 PLIES #181
BELOW WL195
389154-1 RADOME (RAYMOND)
53650-6-2-27

Figure 45. Radome construction (fluted core).

pair to laminated and honeycomb core radomes. Materials needed are fiberglass cloth, honeycomb core, resins, PVA film, foam core and casing, removable propylene mandrel or wax mandrel. The applicable aircraft technical order contains a list of the materials needed for each type of radome. The part or Federal stock number and other information is also given.

16-5. **Repair Methods.** To repair a fluted core radome, use the same sequence as for a honeycomb core radome. Remove the damaged material starting from the outside surface and progress in stages toward the inside surface. To replace the materials you reverse the process. The one exception occurs when the radome is damaged so extensively that a mold (see fig. 46) will be required to form the contour of the facing. First, repair the damaged structural core. Second, repair the inner skin surface (facing). Third, repair the middle membrane. Fourth, re-

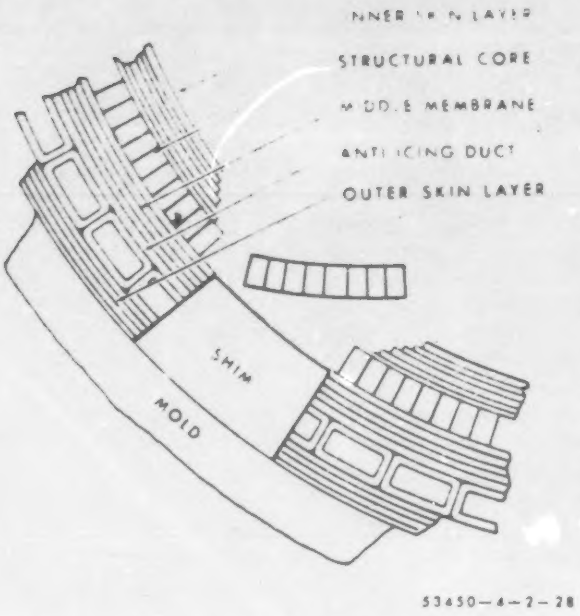


Figure 46. Repair of fluted core radome.

pair the anti-icing duct. Fifth, repair the outer skin layer (facing).

16-6. For damages into or through the de-icing flutes, remove the plies using the step joint method. Remove the damaged flute by carefully cutting vertically down to the opposite face ply. When the middle membrane or inner plies are damaged, use the step joint method. When flutes are not obtainable, perform replacement of fluted core on a section of a mold (wax) conforming to the curvature of the area to be replaced. The flute dimension must be the same as specified by the manufacturer's drawings. Fabricate a replacement section of fluted core with the same processes used during manufacture of the radome. Cut a piece of the performed core from appropriate area and trim to the exact size of the prepared area. Replace the inner ply or plies and the fluted core with the proper resin. Cure under light pressure. Check to make sure the ends of the replacement duct are in proper alinement with the existing duct. A mismated duct could allow pressure to penetrate through the middle membrane and the structural core to the inner layer (facing). This would result in hidden interior delamination. Carefully replace the outer plies. When replacement plies are void-free and smooth, cure it using the manufacturer's instructions.

16-7. **Quality Inspection.** Good workmanship is required. Inspect the completed repair in accordance with the methods previously mentioned for laminated fiberglass enclosures and parts.

16-8. **Safety Precautions.** The general safety precautions to be followed when working on fluted core enclosures and parts are the same as those to be followed when working with mat molded fiberglass repairs.

17. Foam Core

17-1. Some of the small irregularly shaped fire control or "gunlaying" radomes incorporate a "foamed-in-place" core material of one of the formulations based on combinations of alkyd resins and metatoluene di-isocyanate. Foam is used as a lightweight reinforcing material for structural parts. It is used to dampen and eliminate vibration. Foam fills even some of the intricate cavities to overcome fabrication problems. Aircraft parts such as some ailerons, rudders, elevators, and wingtips are filled with foam.

17-2. **Construction Features.** Radomes used on our aircraft, because of their function, are manufactured to very close tolerances on overall thickness, thickness of facings, and thickness of the core material. The materials used must allow the electrical magnetic beam to pass through without being deflected, distorted, or impeded. To achieve this accuracy, the cores are developed by pouring resin into a mold lined with thin layers of fiberglass. The resin immediately foams up to fill the entire enclosure. The close tolerances required for its effectiveness make little allowances for shrinkage or expansion. After the foam solidifies and cures, it is securely bonded to the fiberglass laminates forming a lightweight rugged radome.

17-3. Let me give you a little background information on foam so that you will have a better understanding of its use. Foam is gas-expanded plastic. It is thermosetting, cellular materials obtained by chemical reaction of two components. Several actions take place upon mixture of components, one of which is a gassing reaction which produces carbon dioxide. Formation of the carbon dioxide expands the reacting mass. As the resin sets, the gas remains trapped and retained in the multiple cells it has created within the expanded body of the plastic; for example, the expansion process can be compared to that which takes place as a cake is baked. Baking powder is stirred into the cake mix. When the mix is placed in the oven, carbon dioxide, released by the baking powder, causes the mix to expand (rise). It then becomes a cellular mass in which the cells are filled with carbon dioxide.

17-4. By changing the reacting chemical components, rigid or flexible foams can be obtained. Foamed-in-place cores normally have a density range of between 8 and 20 pounds per cubic foot. Foams are controlled during fabrication to specific densities, depending upon their application.

17-5. An outstanding advantage in the use of foam plastic is that it can be foamed in place to fill any cavity regardless of shape. It is only necessary to pour a sufficient quantity of the mixture into the cavity to insure that the expanded compound fills the entire space. During foaming, the foam adheres well to most surfaces without surface preparation. Foam in its flexible forms is capable of absorbing heavy impact loads with low shock transmission. These open-cell type foams are able to deform readily under load without quick recovery, a characteristic of common flexible materials. Foam plastic has a very low heat transfer. It is unaffected by low temperatures, but is resistant to oils, greases, hydraulic fluids, and aromatic solvents. Because of their cellular structure, foam plastics do not absorb moisture or liquids to any appreciable degree. The foamed material can be easily drilled, sawed, milled, and sanded. Such materials are nonflaking and nondusting.

17-6. Foam is produced by simply mixing two or three liquids at room temperature (if temperatures of components are higher, this high temperature may cause foaming in the container prior to thorough mixing of the materials).

17-7. **Damage Evaluation.** To determine the extent of damage, you must clean the area with an approved cleaner in accordance with the applicable technical order. Do not use MEK as it will weaken foamed-in-place core material. When paint is to be removed, sand lightly, using the grit number of sandpaper given in the applicable aircraft technical order. Remove all of the grit. Visually inspect and classify the damage as mentioned in previous paragraphs for laminated fiberglass. Damage to metal sandwich construction with the foamed-in-place core is inspected and classified by methods mentioned in previous paragraphs for laminated fiberglass construction.

17-8. **Materials, Tools, and Equipment.** The materials, tools, and equipment to be used for repair of fiberglass foamed-in-place core are the same as for laminated fiberglass repairs and fiberglass honeycomb repairs with one exception: the foamed-in-place core *material.*

17-9. The foamed-in-place plastic generally comes in two component or three component formulations. The applicable aircraft technical order will give you the necessary information, by part or stock number, for the pertinent area it is to be used in. For storage of the components, the instructions are generally on the containers. Containers are to be sealed when not in use. Avoid contact with water. Do not store in sunlight as it is conductive to polymerization (change from free-flowing liquid to thick and then hard). Do not store above 120° Fahrenheit. Freezing will not harm the chemical but will make it necessary to heat prior to use. The foams adhere to metal, wood, fiberglass laminates, fabrics, and other materials. When maximum adhesion is required, such as metals, a special coating can be applied with an appropriate primer. Most foams develop sufficient heat during foaming to make them self-curing. When it is necessary to cure with heat, it can be accomplished at temperatures ranging from approximately 150° to 300° Fahrenheit. When close tolerances are to be maintained in thin wall sections, be sure to reinforce the walls. Keep the mixing containers clean.

17-10. **Repair Methods.** The repair principles and procedures for fiberglass foamed-in-place parts are similar to those outlined for fiberglass laminate and fiberglass honeycomb repairs. Select the aircraft applicable technical order. Locate the method or class (II, III, etc.) repair to plastic sandwich with a foamed-in-place core. Follow the instructions contained in the applicable aircraft technical order.

17-11. To give you repairs more easily understood, we have classified the damages into three basic classes. A Class I repair is a scar, scratch, surface abrasion, or minor rain erosion not penetrating through the facing. The repair for these damages is the same as given for laminate fiberglass enclosures and parts.

17-12. A Class II repair consists of a damage extending through two plies of the plastic facing, or completely through one facing and possibly into the core. To repair damage facings use the step joint method (same as fiberglass laminate repair). For damage to one facing and core, use the step joint repair for the facing, one exception being to allow a minimum of one-half inch between the edge of the innermost ply and the periphery of the core material that is to be removed.

17-13. Remove damaged foam area by cutting vertically to the surface of the face laminate. Scrape the inner skin surface clean, avoiding dirt, oil film, or grease in the area to insure good bondage of the foam to the face laminate. Use an approved cleaner as listed in the applicable aircraft technical order.

CAUTION: *Do not use MEK, acetone, or toluene cleaner, since they will soften and weaken the foam core surrounding the cutout area.*

17-14. The cutout form area can be replaced by several methods. A cured foam plug of matching density and thickness to existing core may be cut to fit precisely in the area of the core hole without bonding resin on the sides. Another method is to use a foam mix according to manufacturer's instructions and pour into the cavity. Other methods are used: for example, by using the vertical fin tip assembly on the F4C aircraft, damage to a foamed-in-place core can be repaired with an epoxy filler compound. When the foam is cured, smooth out the surface and contour the filler to the surface of skin laminations. Replace the removed skin laminations.

17-15. Class III repair is made to fiberglass enclosures and parts on which both facings and core have been damaged. The repair is made by removing and replacing the damaged face plies and core materials as previously outlined for Class II repair. Never remove inner and outer fiberglass face plies at the same time. One facing must be completed before repair is made on the opposite facing.

17-16. To make this repair, you must provide the opposite side of the sandwich material with a temporary mold or block to hold the core or foamed-in-place during the first face ply buildup. You can use a shim simulating the thickness of the opposite side facing and secure it in place. After the mold or shim is securely in place, you are ready to replace the laminate facing. Be sure the mold or the shim conforms to the contour or curvature of the part. Replace laminates on the one face, cure repair, and remove the mold or shim. Make the cutout play area approximately 2 inches larger than the first ply cutout area on the opposite side (face) repair (stepjoint method). This prevents the joints of the inner and outer repair area from being in the same position. Continue the repair in the same manner as you did in Class II repair. Study figure 44 before making either a Class II or a Class III repair.

17-17. **Quality Inspection.** Inspecting the completed repair is the same as previously mentioned for laminated fiberglass repair. The coin method is used to check for delaminations.

17-18. **Safety Precautions.** The general safety precautions to be followed for making repairs are the same as those for mat molded fiberglass repairs.

18. Removal and Replacement of Enclosure

18-1. Whenever you remove or replace plastic enclosures and parts, care must be exercised. The necessity for the utmost care to prevent damage cannot be overemphasized. Radomes (radar and radio antenna housings) are especially susceptible to damage. Damage can be minute and invisible but when subjected to vibration, stress, or liquids (water or oil), it deteriorates. Microwave distortion and energy losses occur as a result of cracks, punctures, and other physical damage, including moisture and oil contamination.

18-2. **Handling.** Let us again emphasize that plastic enclosures and parts must be handled with utmost care. Never place enclosures and parts on rough surfaces and among metal parts. Many radome damages result from striking them against workstands, dropping, and dragging on rough surfaces. Plastic enclosures must always be placed on padded dollies and surfaces.

18-3. **Repairing and Plugging Predrilled Attachment Holes.** Occasionally the drilled attachment holes (around the edges or in solid laminate portion of enclosures) require plugging. The holes can be repaired as follows:

(1) Sand the hole thoroughly to roughen the surfaces. Clean thoroughly using MEK or other approved cleaners.

(2) Use fiberglass strands, ⅛ to ¼ inch in length, and mix with catalyzed resin. Form a paste or puttylike mixture.

(3) Press the mixture into hole and cover with cellophane or a parting film. Work out all air pockets (bubbles). Cure at temperatures recommended by the resin manufacturer.

(4) After curing, remove parting film. To remove excess resin and obtain smooth surface, wet sand the area. Consult the technical order for instructions and resin to use. Remember, this repair is for previously drilled holes. Other damages will be repaired in accordance with the applicable technical order.

18-4. **Sanding or Shaving Fiberglass Edge Bands.** Here let us give you information on the installation of a plastic enclosure. Adhere closely to the instructions given in the applicable aircraft technical order. The laminate sandwich construction of enclosures can withstand heavy loads and stresses when applied to the overall part. Localized pressures and sharp impacts can result in delamination of enclosure and parts. Do not hammer or exert unnecessary pressure on the enclosure with your hands or tools. A little pressure can be exerted over the solid laminate edge band area for the purpose of fastening the enclosure in place. When fitting the enclosure into the mounting frame, sanding or grinding of the edge band is permitted, providing you do not sand into the fiberglass cloth. When you sand or grind the edge band, it must be classified as a Class I repair and reworked accordingly.

18-5. **Applying Sealant.** Some edge bands on radomes require sealing because of porous edge laminates. Water also enters through rivets, boltholes, and hardware which must be sealed with a sealing compound. All radomes do not have to be sealed. only when a water contamination problem exists. The requirements for edge band sealing is determined by the appropriate directorate of material management and directed by applicable work specifications.

18-6. When it is necessary to seal edge bands, follow instructions given in the applicable technical order for the specific aircraft. When the specific aircraft technical order is not available, follow the instructions in TO 1-1-24. Apply sealants to rivets, bolts, and hardware. Use the techniques and methods mentioned in earlier paragraphs. The following is a brief outline of procedures for sealing:

(1) Clean the area and metal in accordance with standard cleaning procedures.

(2) Mix sealants in accordance with the manufacturer's instructions.

(3) Apply it with a suitable sealant gun or spatula.

(4) Apply it to the thickness required by the aircraft technical order.

(5) Repair damaged sealant by removing loose particles. Lightly notch the adjacent sealant to obtain a rough surface for better adhesion. Clean the reworked area and reseal in accordance with the technical order.

18-7. **Applying Aerodynamic Smoothers.** Apply aerodynamic smoother to areas required by the aircraft technical order. For application of smoothing compound use the techniques and method discussed in earlier paragraphs.

18-8. The repair techniques presented in this chapter have been simplified. You must realize that personnel having no experience with the materials and techniques involved in making repairs, required on-the-job or special training to acquire the skill necessary for making acceptable repairs.

Metal Bonded Honeycomb

BECAUSE OF ITS close resemblance to a cross section of the comb that bees construct for the storage of honey, the structural sandwich type material you are about to study has been given the name "honeycomb." Let's define structural sandwich construction as "three or more laminations (layers) of different materials that act as one unit when they are bonded (glued) together." The honeycomb structure is manufactured from such materials as aluminum foil, glass fabric, stainless steel, or titanium formed in the shape of hexigonal cells. The finished product (honeycomb core between upper and lower facings) has more strength per pound than any other type of fabricated material presently known.

2. In this chapter you will study the characteristics of this type construction, detection of damage, material, tools, equipment, and the methods used in repairing metal bonded honeycomb. In addition you will learn how to inspect completed repairs and the safety precautions to be taken during inspection.

3. Repairs made to bonded honeycomb differ from repairs made on older aircraft in the methods, limitations, and materials used. Do not be alarmed at the seeming similarities between the material discussed in this chapter and our previous explanation of radome sandwich construction and repair. A comparison of the information will help you learn the specific skills needed in the repair of metal bonded honeycomb structures and parts.

19. Honeycomb Assemblies

19-1. Metal bonded honeycomb construction design is governed by the intended use of the panel or structure and is found in a variety of shapes and sizes. These aircraft components may consist of a whole section or a series of panels combined into an assembly. Metal bonded honeycomb is used as a flat or curved panels in bulkheads, control surfaces, fuselage panels, wing panels, empennage skins, etc.

19-2. Metal bonded honeycomb (sandwich construction) consists of a core bonded between two metal facings by means of an adhesive or resin (see fig. 47). The honeycomb core is bonded to and between the two facings to produce a panel that is highly resistant to bending and yet is elastically stable to withstand high stresses. This type of construction has a superior strength-to-weight ratio over the metal structures used on older type aircraft. It can withstand sonic high-frequency vibrations caused by the exhaust of jet engines used on modern aircraft. Bonded honeycomb construction costs less than old fastening methods, as fewer installation parts are required. Sealing problems are reduced by the use of honeycomb and the finished product is more aerodynamically smooth.

19-3. Special types of metal bonded honeycomb construction may be made of stainless steel, titanium, magnesium, wood, resin impregnated paper, glass, nylon, or cotton cloth in various combination.

20. Honeycomb Damage

20-1. Along with an increased use of honeycomb construction in modern aircraft, a certain amount of damage to this type of structure is sure to occur, but such damage may be reduced by improved maintenance and handling procedures.

20-2. Most damage to honeycomb assemblies is caused by flight loads, ground handling, and sonic vibrations. Sonic vibrations and moisture usually cause a delamination: that is, a separation of the core and face along the bond line—the thin line of adhesive between the core and face that holds the two together. Inspection for damage is more critical for metal bonded honeycomb assemblies than for conventional structures, because honeycomb structure can have extensive hidden damage that is not easily seen during routine visual checks.

20-3. **Inspection Methods.** Structural parts must be carefully inspected for areas that have

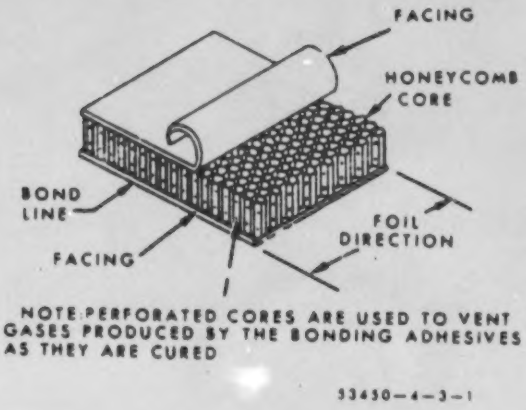

FACING
HONEYCOMB CORE
BOND LINE
FOIL DIRECTION
FACING
NOTE: PERFORATED CORES ARE USED TO VENT GASES PRODUCED BY THE BONDING ADHESIVES AS THEY ARE CURED
53450—4—3—1

Figure 47. Bonded honeycomb.

poor bonding between facings and core. Areas having no bond are usually readily detectable by several of the common inspection methods, but areas having weak bond strength are exceedingly difficult to locate by visible inspection or nondestructive test methods.

20-4. *Tapping*. Tapping is one of the most simple and effective methods for testing for voids or delaminations in the adhesive bond between the facings and the core of a sandwich part. This is also called the metallic ring test. The only equipment necessary for this test is a small metal piece such as a coin (25¢ piece) or a light 1-ounce aluminum hammer (see fig. 48) that can be manufactured locally. During inspection by the tapping method, parts should be freely supported on three padded points to eliminate sound interference from supports. A well-bonded area will produce a clear tone, a poorly bonded area a lower tone or a dull thud.

20-5. The tapping method is satisfactory for detecting delaminations, where the facings are not firmly attached to the core. If the delaminated facing and core are still in close contact it is difficult to detect any difference between the "tapping tone" produced by these areas and by the well-bonded areas. Poorly bonded areas cannot always be identified from well-bonded areas by means of tapping, but light tapping will give better indications than heavy blows. Considerable experience is required to locate defective areas, as parts of different construction will give off different tones. The tones on the same part will also vary, depending on the position you check; for example, variation in tone is especially noticeable within a few inches of the edge.

20-6. *Spur wheel*. An instrument used in place of the tapping hammer is the "spur wheel" (see fig. 49). When testing with the spur wheel, run it at a constant speed across the sandwich part

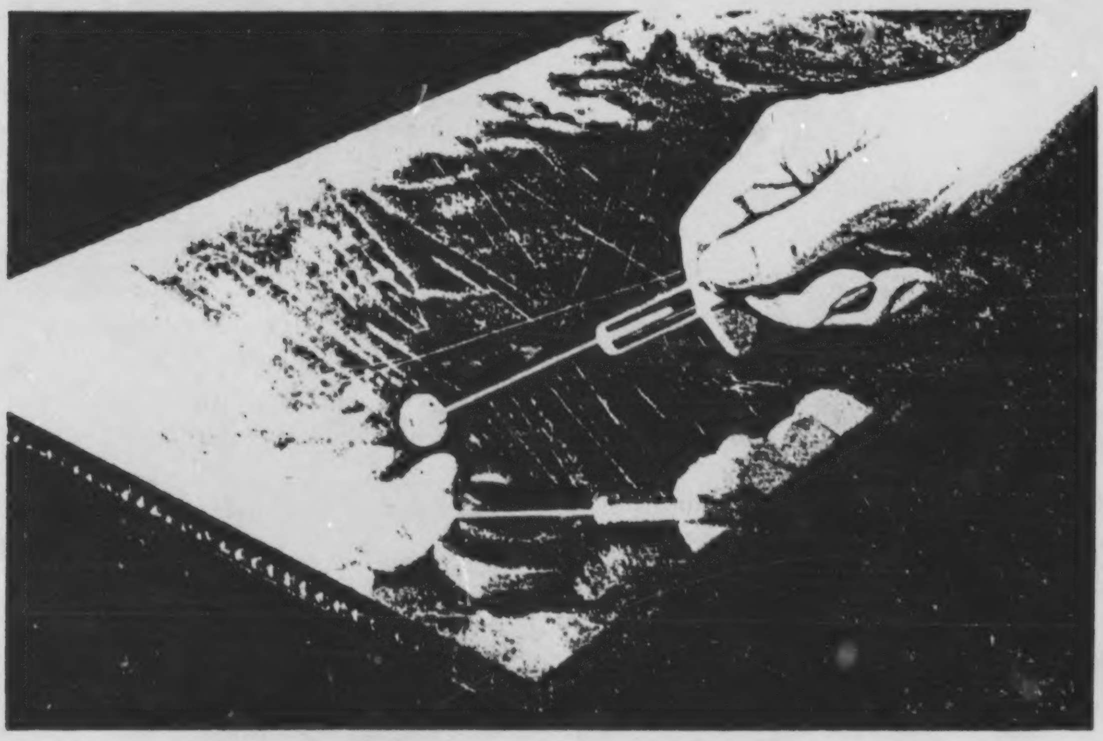


Figure 48. Light tapping hammer.

and listen for a change in tone. Make certain the teeth on the wheel are equally spaced or the wheel itself will produce a difference in tone.

20-7. *Visual.* Occasionally the delaminated skin will "oil can" away from the core, making visual or thumb pressure detection possible. Punctures, dents, scratches, cracks, and such may be inspected by conventional methods. Scratches, should be given special attention because a scratch on the thin metal used in metal bonded honeycomb may be a crack.

20-8. *Caustic soda solution.* A caustic soda solution can be used for locating deep scratches on aluminum surface panels. If the area turns black after an application, the solution has penetrated through a scratch in the clad surface.

20-9. *Dye penetrant.* When you visually inspect an aircraft part or component and suspect some hidden defect which could cause material failure, you may verify a crack by using a dye penetrant. A penetration inspection can be used on most aircraft materials, except on shot-peened areas. It will give you positive indications on structures such as formed sections, extrusions, forgings, and skins.

20-10. In making a penetrant inspection, coat the surface with a suitable liquid film and allow time for the liquid to work into the surface. When the surface liquid is removed, the liquid remaining in the cracks or discontinuities reveals the breaks in the material. Visual examination of the surface will reveal a color in the defects; or under a black light the material will show fluorescence of a brilliant greenish-yellow. There are three methods of performing penetrant inspection tests: (1) fluorescent, (2) postfluorescent, and (3) nonfluorescent. The selection of the correct testing process depends on the number of parts to be inspected, surface conditions of metal, size and configuration of part.

20-11. The part inspected must be clean and free of any foreign materials such as acids or chemicals, as they will affect the value of the penetrant. Most oils and greases are fluorescent and will tend to give a false color indication. Oils and water can also prevent the penetrants from entering the cracked areas. For detailed information on the application and usage of the

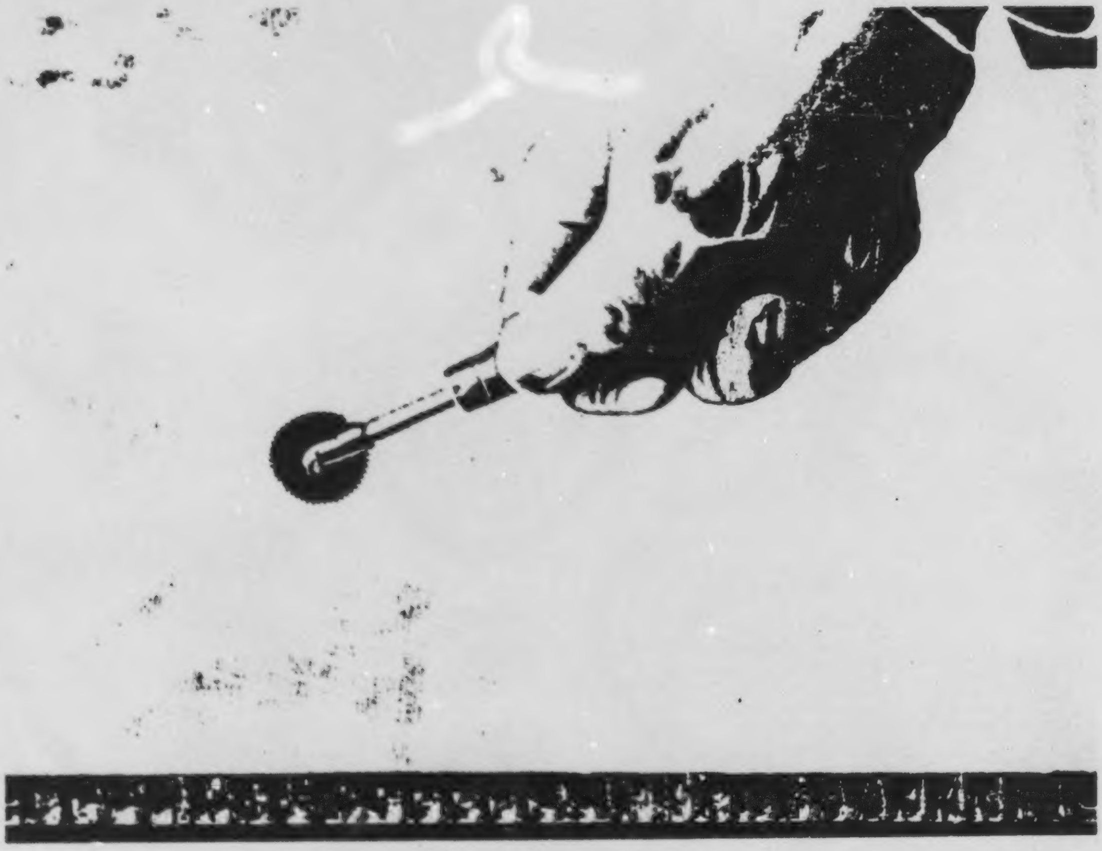


Figure 49. Spur wheel.

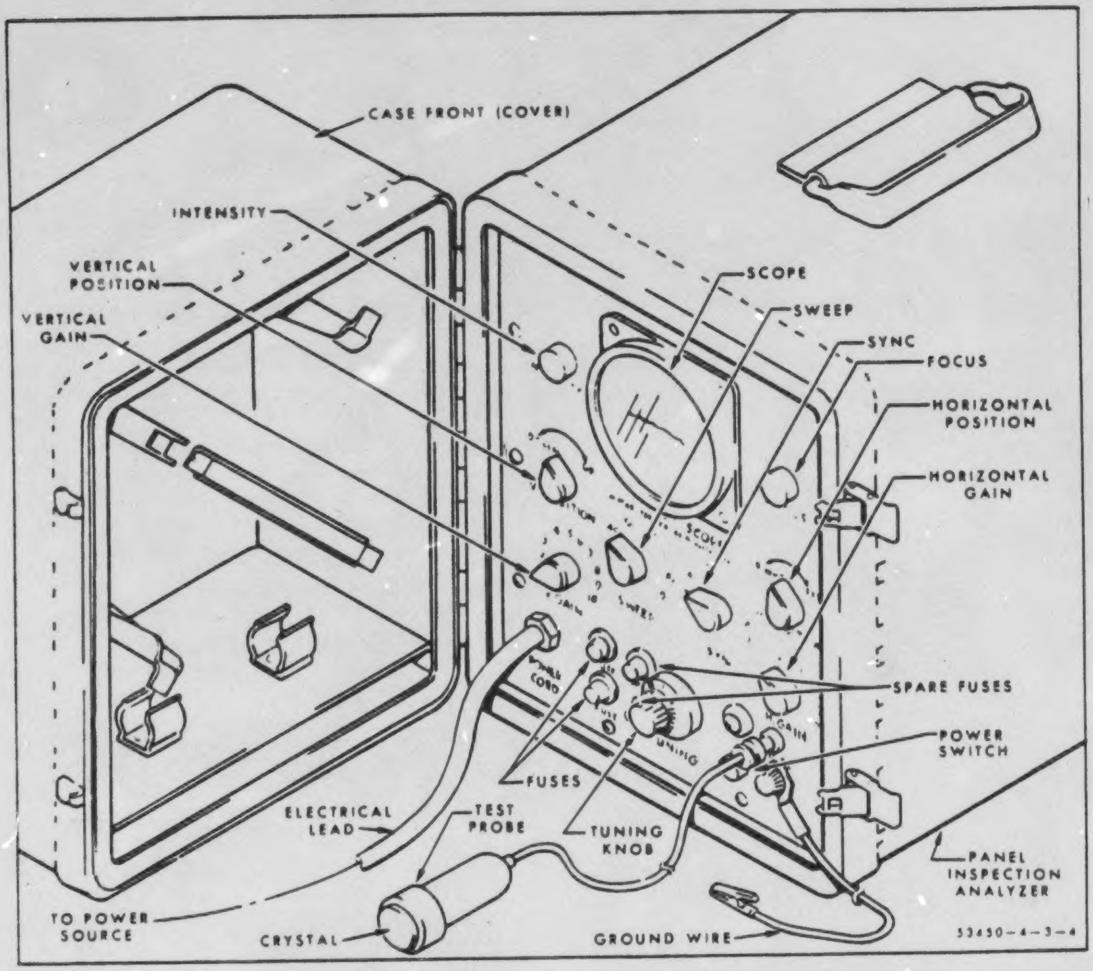

CASE FRONT (COVER)
INTENSITY
VERTICAL POSITION
VERTICAL GAIN
SCOPE
SWEEP
SYNC
FOCUS
HORIZONTAL POSITION
HORIZONTAL GAIN
POWER CORD
SPARE FUSES
POWER SWITCH
FUSES
ELECTRICAL LEAD
TEST PROBE
TUNING KNOB
PANEL INSPECTION ANALYZER
TO POWER SOURCE
CRYSTAL
GROUND WIRE
53450-4-3-4

Figure 50. Panel inspection analyzer.

different penetrants, consult the technical manual or structural repair instructions (-3 TO) of the particular aircraft.

20-12. *Panel inspection analyzer.* Other instruments used in the inspection of bonded panels are the panel inspection analyzer (sometimes referred to as stub meter or coindascope) and the boroscope.

20-13. The panel inspection analyzer (see fig. 50) is a self-contained, one-cabinet, ultrasonic instrument, engineered for testing of bonded structures. It is an electronic instrument having a piezolelectric (electric polarity which is due to pressure) crystal driven by a variable frequency current of constant amplitude. The variations in voltage, which develop across the face of the crystal, are proportional to the amplitude of the crystal's vibration. They are shown as a fluctuation frequency on the face of an oscilloscope (an instrument for showing the changes in varying current).

20-14. The pattern displayed on the oscilloscope shows the characteristics of the crystal's vibration. The crystal is coupled to a bonded panel (in a manner similar to that of a doctor using his stethoscope to listen to your chest); it records information regarding the bonded panel's vibration, thus revealing its physical characteristics.

20-15. The purpose of inspecting the bonded panels with the panel inspection analyzer is to detect nonstandard bonds, voids, and other similar defects. Standard bonded panels are used to standardize (set up) the inspection analyzer prior to testing bonded panels. The standard panels should have the same physical characteristics, size, shape, and bonding qualities as the honeycomb panel being tested. To standardize the panel inspecting analyzer, you compare a good test panel with a possible defective panel.

20-16. A typical inspection analyzer is shown in figure 51. Closely observe all wiring connections and test panel set up and you will see how the test probe is used to locate damaged areas. Also note how the damaged area is circled on the assembly to be tested. It is important that all connections be made as shown in figure 51. For a more detailed illustration of the control panel, refer to figure 52. Study this illustration closely, as it will be very similar to the analyzer you will be using in the field. For a more detailed explanation of the panel inspection analyzer, refer to the applicable technical order. Figure 53 illustrates signals received on the panel inspection analyzer. The illustration on the left in figure 53 shows a standard void image and the one on the right a standard bond image.

20-17. **Damage Evaluation.** After you finish inspecting the metal bonded honeycomb, evaluate any damage found. Determine the type of repair that is needed to make the structure serviceable. Damage evaluation charts are found in the applicable section of the –3 technical order for the specific aircraft. The charts specify types of damage, allowable damages, damages requiring repair, and the figure numbers for illustrations of typical repairs for each type of damage. After deciding what type of repair is needed, you should closely follow technical order procedures.

21. Honeycomb Repair

21-1. Specific recommendations as to the type of repair and procedures to use vary among the manufacturers of aircraft. We will discuss tools, materials, and equipment, and typical repairs that could be made on metal bonded honeycomb structures. The applicable section of –3 technical order for the specific aircraft should be consulted prior to making any repair.

21-2. **Tools and Equipment.** Effective repairs to bonded honeycomb assemblies depend largely on the airframe repairman's knowledge, skill, proper use, and maintenance of the repair tools

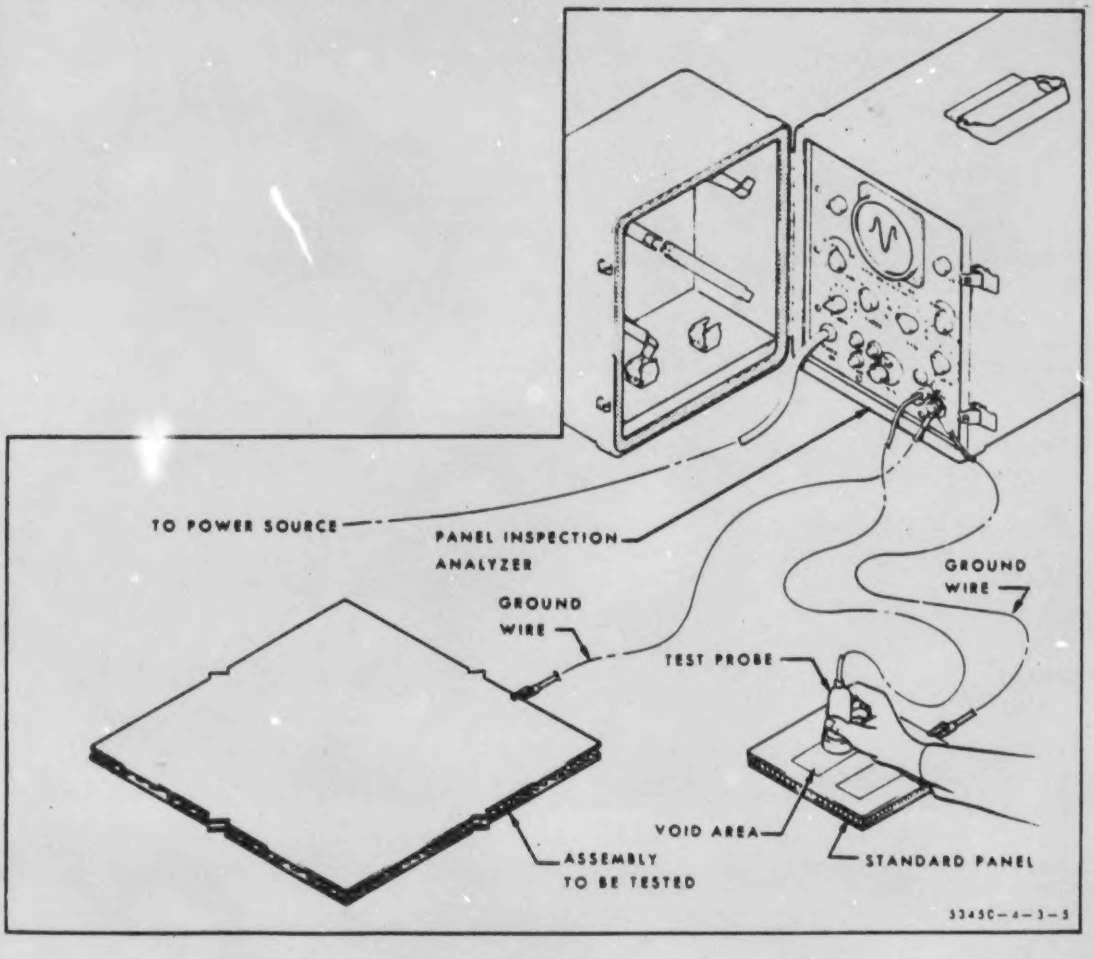


Figure 51. Panel inspection analyzer setup.

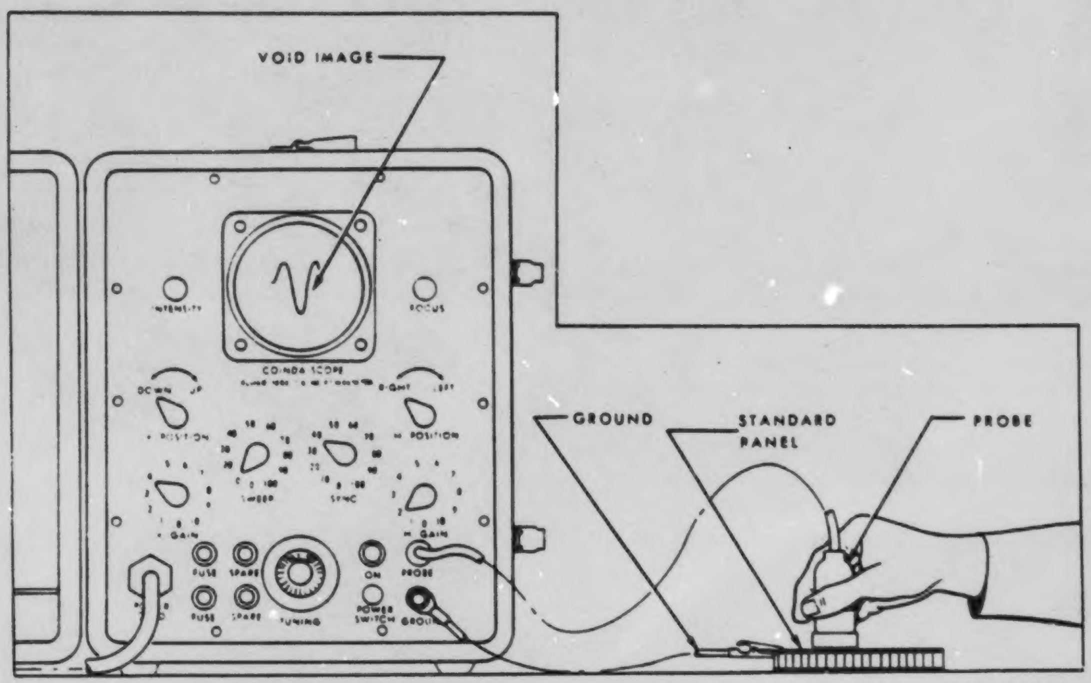


Figure 52. Panel inspection analyzer instrument panel.

and equipment. The design and high quality of workmanship built into these tools and equipment make them unique in the repair of bonded honeycomb assemblies. It is essential that an airframe repairman know and practice the techniques and procedures set up for each tool or piece of equipment to avoid personal injury and additional damage to the part being repaired.

21-3. *Router equipment.* The primary tool used to prepare a damaged honeycomb area for repair is a pneumatically powered, hand-operated router with speeds ranging from 10,000 to 20,000 rpm (revolutions per minute). The router explained earlier when we discussed routing of plastics is used with the support assembly, bit, and template, as shown in figure 54. Router templates are used as guides when you are removing damaged honeycomb areas with a router. They may be designed and manufactured to fit the various sizes, shapes, or contours of the repair you are making. As an example, the multitemplate (fig. 55) can be used as a guide when cutting holes from ½ to 6 inches in diameter. For larger holes, a template may be locally manufactured from aluminum alloy 0.125 inch in thickness; smaller holes may be cleaned without the use of a template. The multitemplates should be kept clean and lightly oiled to prevent rusting and to maintain smooth operation during their use.

21-4. *Use of router equipment.* A routing template can be used on a flat surface by applying double-backed tape to the edge of the template and centering it around the damaged area. The template should be pressed down firmly on the double-backed tape to eliminate creeping or misalignment.

21-5. When using a routing template on a tapered surface, make a bridge of two manufactured wedge blocks at least 6 inches long and approximately the same degree of angle as that of the panel (see fig. 56). Apply double-backed tape to the top and bottom of the wedge blocks, which are placed on each side of the damaged area. Correctly position the template on the wedge blocks and press down firmly on the dou-

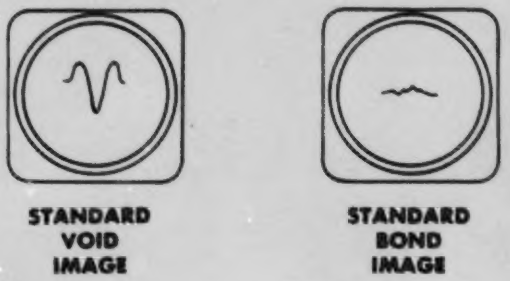


Figure 53. Panel inspection analyzer signal reading.

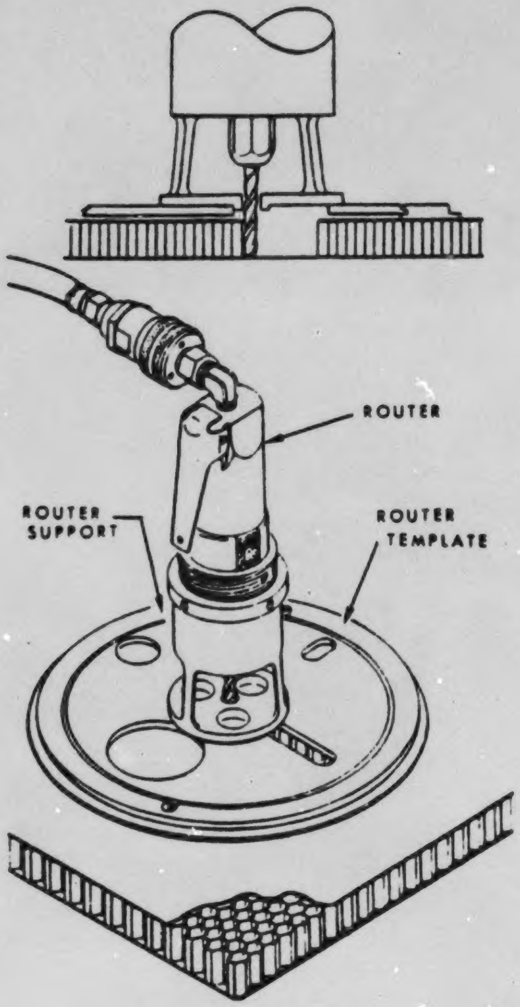


Figure 54. Router, support assembly and template.

ble-backed tape to prevent any creeping or misalignment.

21-6. When removing damage from bonded honeycomb, closely inspect the damaged area to determine how much should be removed. The router and template should be set up to insure the correct amount of damage that will be removed. Start the router at a 45° angle, gradually straighthen it to a perpendicular position and move it in a clockwise direction to the outer limits of the template until all damage is removed. If more damage needs to be removed, repeat the entire operation. When aluminum core cells are damaged or tend to be closed during the routing operation, open them with tweezers or a penknife. Trim the core cells with a penknife to better shape the repair hole.

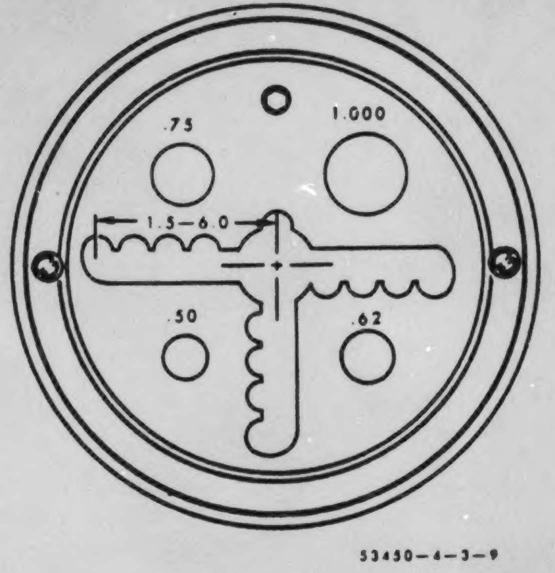


Figure 55. Multitemplate.

21-7. *Pressure jigs.* Pressure jigs are used to apply pressure to repairs on under surfaces of honeycomb panels or assemblies in order to hold the repair materials and resins in place. The pressure is maintained on the repair area until the repair is cured. C-clamps, locally manufactured jigs, or vacuum fixtures may be used to apply the necessary pressure.

21-8. You must keep the surfaces around the repair area absolutely clean and free of any foreign materials in order to insure a good vacuum

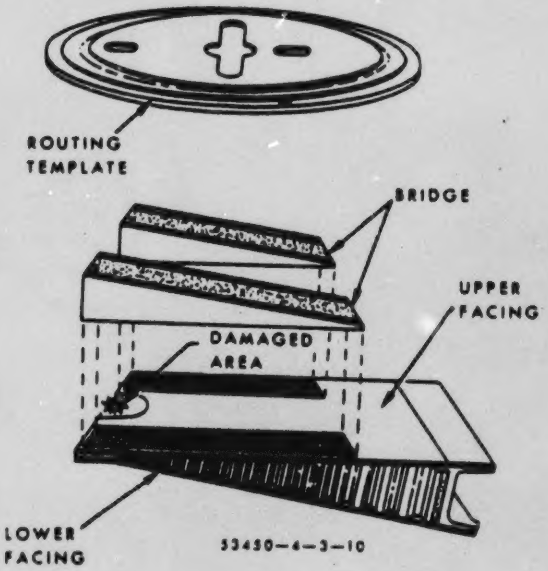


Figure 56. Wedge blocks and application.

when using vacuum (suction) type equipment. An application of water or glycerin to the surface areas will aid in obtaining a good vacuum. Normal cleaning, care, and corrosion prevention keep the equipment in good working condition.

21-9. *Scales.* Accurate mixing of the adhesive ingredients by batches is considered one of the more important steps in the repair of bonded honeycomb structures. Information of the correct proportions of the epoxies, resins, and microballoons to be mixed into batches (both by weight and/or by volume) is given in the applicable section of the –3 technical order for the specific aircraft.

21-10. Scales generally used in the weighing of adhesive ingredients are of the balance type with an upright center, indicator, and weight sets graduated in grams. Although balance type scales are very sensitive, they are very simple to use. The scales may be used in weighing the adhesive ingredients by part or gram weight. In order to get accurate readings, the scales must be kept clean; misuse of the scales or any accumulation of the waste materials will affect the scale's free movement and accuracy of its readings.

21-11. *Infrared heat lamps.* Infrared heat lamps are used to shorten the curing time of bonded honeycomb repairs from approximately 12 hours to 1 hour. A single-bulb lamp will adequately cure a repair up to 6 inches in diameter; but a large repair may require a battery of lamps to insure uniform curing of the repair area.

21-12. Center the lamps directly over the repair at a distance of about 30 inches. The setup is ideal to attain the recommended 130° F. curing temperature provided the surrounding areas are at room temperature (70° F.). Warmer or colder surrounding areas require that you adjust the heat lamps to the prevailing condition. You must exercise caution when working under arctic conditions, as a temperature differencial of 150° or more will cause buckling of the surrounding skin surfaces, due to thermal expansion.

21-13. As with any ordinary light bulb, the infrared bulb requires little or no maintenance; however, the support stands, wiring, and switches should be handled carefully and maintained properly.

21-14. *Explosive meter.* The explosive meter is an instrumented device which detects and indicates the amount of combustible gases. Before this instrument is used for the detection of combustible areas, turn it on and purge (clean out) any existing vapors lingering from the previous test by pumping the attached aspirator bulb. Then extend the sampling tube to the area to be tested and pump the aspirator bulb again. The highest reading the indicator gives is the maximum explosive hazard in the tested area. If the explosive hazard is above the allowable limits, you should completely ventilate the area until a safe working condition exists.

21-15. The primary maintenance of instruments that use dry cells and filaments (such as the explosimeter) consists of replacing the parts as necessary. Calibration of the indicator must be performed by a qualified instrument specialist.

21-16. *Honeycomb structural repair kit.* The honeycomb structural repair kit is a portable cabinet containing the necessary tools, equipment, and materials required for metal bonded honeycomb repairs. Included in the repair kit are the following special pieces of equipment and materials:

- Vacuum-heating blanket.
- Vacuum pump.
- Thermocouple.
- Potentiometer.
- Armalon fabric.
- Pressure plate.
- Vent cloth.
- Double-backed tape or vacuum bag compound.

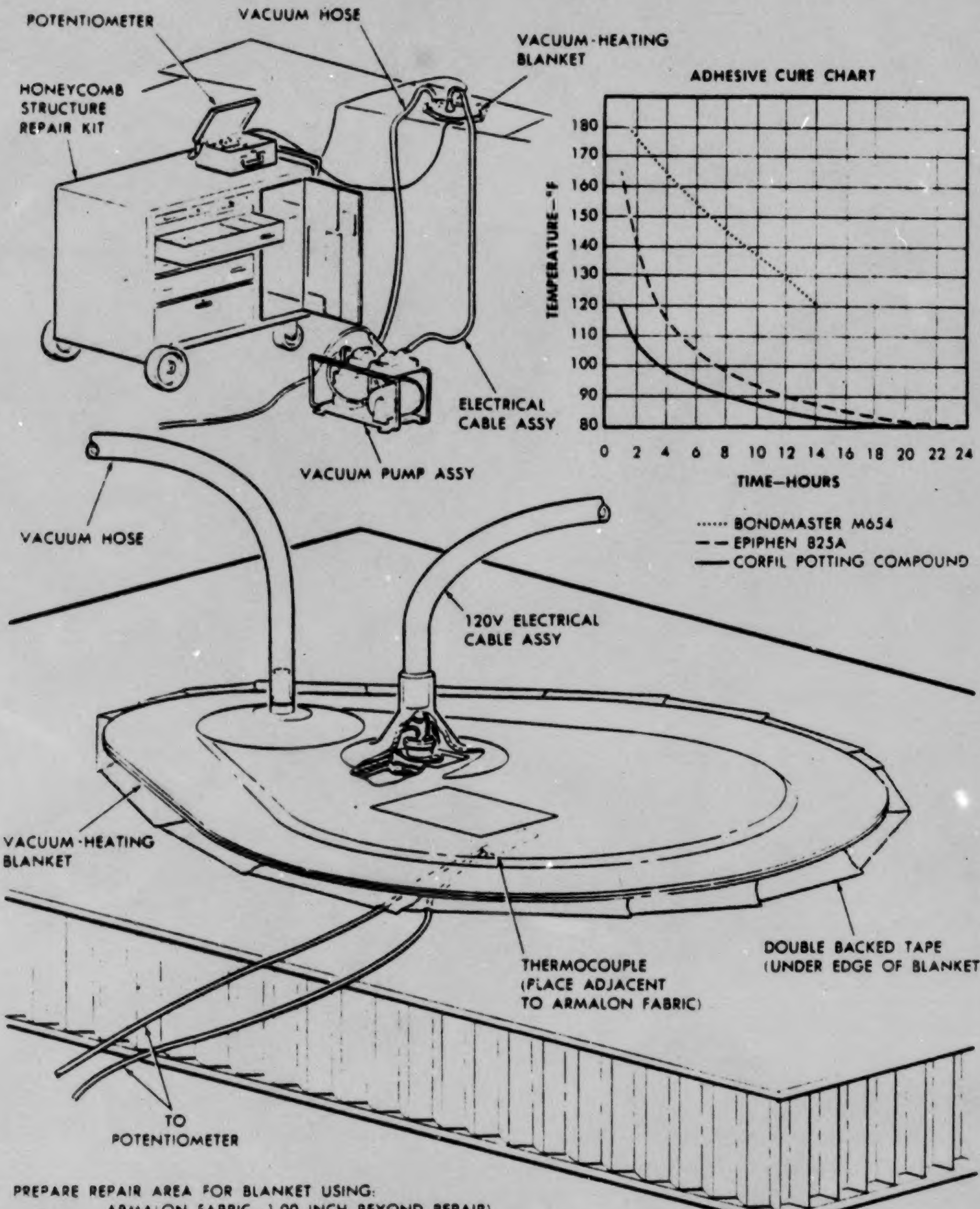
Figure 57 is a typical setup for a honeycomb repair in which the honeycomb structural repair kit is to be used. For more detailed information on the use of materials and equipment in the repair kit consult the proper section of the applicable –3 technical order for the specific aircraft.

21-17. **Fire Precautions.** The potential possibilities of a fire hazard generally exist in the area of bonded honeycomb repairs because of the low flash point of repair materials such as cleaning solvents, primers, resins, etc. It is necessary that all fire precautions be closely observed at all times. Certain fire safety prevention equipment such as utility cans, nonflammable waste cans, and vapor- and explosion-proof lights should be used.

21-18. Always keep in mind the potential for fire hazards in a honeycomb area, and make sure that a suitable fire extinguisher is on hand or located nearby and ready for use. The extinguishing agents for all of the materials used in bonded honeycomb repairs are dry chemicals or carbon dioxide. Since the CO_2 fire extinguishers may be obtained and maintained locally, they should always be on hand and used in areas where bonded honeycomb structure repairs will be made. Use CO_2 fire extinguishers where necessary in accordance with standard procedures.

21-19. **Handtools and Equipment.** In addition to the special tools and equipment described in the preceding paragraphs, standard handtools and shop equipment are used in the repairs of bonded honeycomb structures. These include the airframe repairman's toolkit, face shield, scissors, power shear, drill press, horizontal and vertical belt sanders, contour metal cutting saw, and pneumatic hand drills. The general uses and maintenance of these standard tools and equipment should be familiar to all airframe repairmen.

21-20. **Repair Materials.** The proper selection of repair materials for a specific honeycomb repair should be made only after consulting the -3 technical order for the given aircraft. The im-


POTENTIOMETER
VACUUM HOSE
HONEYCOMB STRUCTURE REPAIR KIT
VACUUM-HEATING BLANKET
ADHESIVE CURE CHART
TEMPERATURE—°F
180
170
160
150
140
130
120
110
100
90
80
0
2
4
6
8
10
12
14
16
18
20
22
24
TIME—HOURS
...... BONDMASTER M654
— — EPIPHEN 825A
—— CORFIL POTTING COMPOUND
ELECTRICAL CABLE ASSY
VACUUM PUMP ASSY
VACUUM HOSE
120V ELECTRICAL CABLE ASSY
VACUUM-HEATING BLANKET
THERMOCOUPLE (PLACE ADJACENT TO ARMALON FABRIC)
DOUBLE BACKED TAPE (UNDER EDGE OF BLANKET)
TO POTENTIOMETER

PREPARE REPAIR AREA FOR BLANKET USING:
ARMALON FABRIC (1.00 INCH BEYOND REPAIR)
ALUMINUM PRESSURE PLATE (0.064 INCH AND SAME SIZE AS FABRIC)
VENT CLOTH (4.00 INCHES BEYOND PLATE)

Figure 57. Typical honeycomb repair kit setup.

portance of the correct materials for a specific repair cannot be overemphasized. Improper selection of materials will definitely result in poor or unacceptable repairs.

21-21. *Cleaning solvents.* Before a repair is made to a bonded honeycomb structure, an area extending several inches away from the damage must be cleaned thoroughly of all paint or surface coating. This is best accomplished by the use of paint remover AF Specification 14119C or methyl ethyl ketone cleaning solvent. In some cases, Alconox, a powerful wetting and detergent agent, may be used for a final cleanup to remove any residue or oils remaining after application of the paint remover or the MEK cleaning solvent.

21-22. Paint removers are applied with a suitable size brush. When the paint or surface coating has loosened, it is either wiped off with a clean rag or removed with a nonabrasive scraper. Paint remover must not be allowed to enter the damaged area or be used along a bonded joint or a seam, because its chemical action will dissolve the bonding adhesive. These areas should be masked and final cleanup done with the MEK cleaning solvent or an emery cloth. The MEK cleaning solvent and the Alconox cleaning agent may be applied with a clean sponge.

21-23. After a damaged area has been completely removed, thoroughly clean the surrounding surface areas. This is done by the use of the MEK cleaning solvent and gauze sponges. Apply the MEK cleaning solvent to the area with one sponge and immediately wipe it off with another before it has had time to dry. Continue this cleaning process until the surface area is lustrous in appearance and clean of all foreign matter.

21-24. To determine whether an area is completely and thoroughly clean, use a water "break" test. This test is a simple application of a thin film of distilled water to the cleaned area. Any "break" of the applied thin film of distilled water will indicate that the area has not been cleaned enough and that the process must be repeated. Observe safety precautions closely when you are working with these cleaning solvents, especially when the work is overhead or in confined areas. For your personal protection, wear rubber gloves, face shield, and a respirator. Again let us emphasize that a CO_2 fire extinguisher should be on hand or nearby and ready for use in case of fire.

21-25. *Primers.* Primers are applied to the cleaned surface areas primarily to insure a good bond of the honeycomb repairs. A primer used in the repairs of bonded honeycomb structures of the B-52 aircraft is known as EC-776R. This primer is applied to the clean surface areas with a clean gauze sponge or brush. It is recommended that you apply this primer as rapidly as possible because it will become tacky in 10 to 15 seconds; then it will pull and be ruined by any further brushing. The EC-776R primer will cure in approximately 1 hour at room temperature; however, this time may be reduced by the application of controlled heat. The primer must be dry for proper adhesion of fiberglass cloth laminates.

21-26. *Adhesives and resins.* Two types of adhesives presently used for making repairs on bonded honeycomb structures of some aircraft are known as the *fiberglass adhesive* and the *potting compound.* The fiberglass adhesive is applied to glass fabric overlay repairs; the potting compound is used (as the name implies) for hole filling, that is, with potting compound repairs. In addition, the fiberglass adhesive may be used as an alternate for the potting compound by adding (microscopic phenolic) microballoons. The adhesive or potting compounds are prepared according to a batch mix (amount required for the repair) formula. The batch mix should be measured by weight.

21-27. The fiberglass adhesive is a mixture of equal parts of low viscosity liquid resins (Epon 812 and Epon 828) with equal mixture by weight of curing agents (Versamid 115 and Versamid 125). Mixing procedures for a batch mix is as follows: mix equal parts (by weight) of the Epons, mix equal parts (by weight) of the Versamids, then mix the Epons and the Versamids together. This patch mix of fiberglass adhesive has a pot life of about 2 hours. The fiberglass adhesive will cure in 12 hours at room temperature (70° F.) or 1 hour when the repair area is preheated with heat lamps.

21-28. The preferred potting compound (table 2) is a mixture of Epon 815 (low viscosity liquid resin) and curing agent T, with microballoons added in required amounts to control

TABLE 2
POTTING COMPOUND MIX

		PARTS by weight	BATCH MIX
Epon 815		100	25 grams
Micro-Balloons	Stiff	30	7.5 grams
	Average	24	6.0 grams
	Thin	16	4.0 grams
Curing Agent T		22	5.5 grams

33430-4-3-T1

the viscosity (microballoons have no curing effect). This compound has a bench or pot life of 15 to 20 minutes. The alternate potting compound (fiberglass adhesive with microballoons added) has a pot life of approximately 2 hours. Curing time for the preferred potting compound is about 4 hours at room temperature (70° F.).

21-29. *Core material.* Fiberglass honeycomb core materials ($\frac{3}{16}$-inch cell size) are used to replace the damaged aluminum cores of the bonded honeycomb structures. Aluminum core materials are not satisfactory for the repairs because of their flimsy and fragile structure. With this condition, it is impractical to cut the aluminum core materials accurately to the desired repair size. On the other hand, fiberglass core materials are available in various thicknesses and are easily and accurately cut to size by the use of standard shop tools and equipment.

21-30. *Glass fabrics.* Glass fabrics used in the overlay repairs to bonded honeycomb structures are manufactured from glass. The glass is spun into fibers which are in turn woven into a glass cloth with a variety of weaves. Two layers of adhesive impregnated glass fabric cloth, number 181, are recommended for normal glass cloth overlay repairs because of the flexibility in this particular type weave. Four layers are recommended in the transition area. As an alternate, three layers of impregnated glass fabric cloth, number 128 may be used.

21-31. Glass fabric cloth must be handled with care, stored properly, and be perfectly clean of any dirt, moisture, oil, or other contaminants which may cause imperfect adhesion of the materials with which it is impregnated. Snags and sharp folds in the cloth will cause its strands to break; the result is a local strength loss in the finished repair. Exposure to or contact with the glass fabric, dust, or particles may cause bodily itching or irritation.

21-32. *Erosion and corrosion preventives.* Two coatings of preventives are applied to the bonded honeycomb structure repairs for the protection of the areas against erosion and corrosion. The first is two layers of zinc chromate, preferably sprayed onto the repair area. The second is two layers of aluminum pigmented Corrogard (EC 843), either sprayed or brushed on with a 30-minute drying period between each application. Since both materials are flammable, the necessary fire precautions should be observed.

21-33. **Potted Compound Repair.** The following techniques, methods, and procedures are related to potted compound repairs on B–52G bonded honeycomb structures. When making repairs, consult the applicable section of the –3 technical order for each type aircraft. Technical order procedures should be followed in preference to the information contained in this manual. The information in this manual illustrates only typical examples and is not to be construed as the superior authority.

21-34. You may repair a bonded honeycomb structure up to 1 inch in diameter by the hole-filling technique, using approved materials. The repair method is commonly known as the potted compound repair. It is the easiest and fastest method that an airframe repairman can use to mend a damaged area of a bonded honeycomb structure. However, you must adhere to the techniques, methods, or procedures established for potted compound repairs. Not following prescribed procedures during your attempt at repair may complicate the situation by creating additional damage.

21-35. Potted compound repairs may be applied to both single-face (one skin) and core damages, and to double-face (two skins) and core damages. (See fig. 58.)

21-36. The inspection and evaluation of any defects or damaged areas may be found on bonded honeycomb panels of the B–52 aircraft considered critical. Therefore, the "Damage Evaluation Chart—Honeycomb Structure" should be consulted before any repairs to bonded honeycomb panels or structures are attempted. Information pertaining to the type of damages, allowable damages, and reparable damages, with figure references and notes, are given in this chart.

21-37. Normally, no surface preparation is necessary when you are making potted compound repairs. Oily or dirty surface areas to which multitemplates or pressure jigs are attached with adhesive tape may be cleaned with any approved or recommended cleaning solvent such as MEK.

21-38. Damages ¼ inch or less in diameter may be satisfactorily removed with a twist drill. The multitemplate and a high-speed router

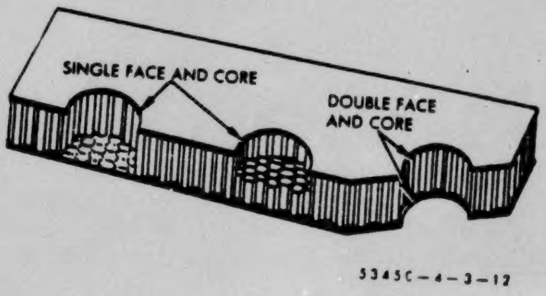


Figure 58. Typical potted compound repair areas.

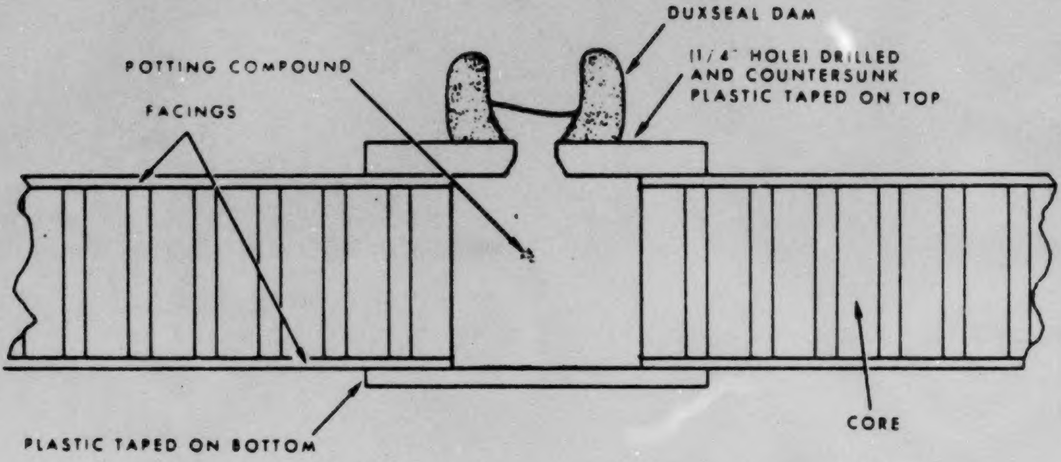


Figure 59. Cross section of typical potted compound repair.

(10.000 to 20.000 rpm) are used in the removal of damaged areas for potted compound repairs up to 1 inch in diameter. The amount of material removed by either method must be kept to a minimum in order to maintain as much of the original strength of the panel or structure as possible. Always use a face mask or goggles when using the router to remove damaged materials.

21-39. After a damaged area has been completely removed and cleaned. the necessary materials for the potted compound repair(s) are prepared. Pieces of sheet plastic materials are prepared to provide a smooth surface effect on the potted compound repair to provide part of the reservoir for the hole-filling operation of the repair and to hold the potting compound in place until it is completely cured. The pieces of sheet plastic used for any of these purposes should be at least ½ inch larger in diameter than the diameter of the hole to be repaired.

21-40. Apply a thinner piece of sheet plastic material (approximately 1/16 inch thick) to the lower (bottom) surface of the double-face repair. (See fig. 59.) This is done not only to give the repaired surface a smooth effect but mainly to hold the repair surface (potting compound) in place until it is cured. The same process may be used with a single-face repair where the work must be done in an overhead position.

21-41. Sheet plastic materials ranging from 1/4 to 3/16 inch in thickness are used on the upper surface of the repair during the hole-filling procedures. A ¼-inch hole is drilled directly in the center to permit easy application of the potting compounds to the repair cavity. The hole is also countersunk to allow a buildup of the potting compound and thus to assure that the repair cavity has been completely filled.

21-42. This piece of plastic material is also a part of the "Duxseal" dam. After the prepared pieces of sheet plastic materials are properly located and taped in place over the repair area, the Duxseal dam is built up around the hole. (See fig. 59.) This dam is partially filled with the potting compound during the hole-filling operation to insure that the cavity of the repair is adequately filled. The Duxseal dam also acts as the reservoir.

21-43. Next, prepare a sufficient batch mix of the preferred (Epon 815 curing agent T and microballoons) potting compound or its alternate (fiberglass adhesive and microballoons) compound for the repair. Fill the cavity with the potting compound and remove the air bubbles with a toothpick or similar tool. By removing the air bubbles, you make sure that the cavity is solidly filled.

21-44. When the potting compound in the repair cavity is completely cured, remove the pieces of plastic. Generally, these pieces are lifted off by hand. If necessary, you may pry them off easily with any dull straight handtool. When you remove the drilled top piece of plastic, a broken stem will be left protruding above the repair surface. This stem may be filed, microshaved, or routed down to make the repair surface area smooth. At least one layer of glass laminate is then placed over the potted compound repair for sealing. This type of application will be discussed in the area pertaining to fiberglass overlays.

21-45. Test the soundness of the repair by the metallic ring method. Use pressure jigs on the undersurface potted repairs as necessary. Surface finish the repair by the application of the recommended coatings of erosion or corrosion preventives and a final coating of a finish of the same specifications as the original finish.

21-46. **Skin Delamination and Crack Repairs.** Skin delaminations occurring in the bonded structures are defined as the separation of the facing(s) from the honeycomb core structure and the splitting apart of the skins or facings. Skin cracks in these structures take on a new meaning: a small scratch or defect may be an actual crack, especially on the thinner materials. When an airframe repairman is confronted with such repairs he must recognize the significance of the new technique, method, or procedure that he encounters during the inspection, evaluation, or repair of delaminated or cracked skin areas. The repair techniques, methods, and procedures given are to be used only as a guide. For specific repairs on a given type of aircraft, consult the applicable section of that –3 technical order.

21-47. Close inspections of bonded honeycomb structures are necessary and of utmost importance. Such inspections not only detect any skin delaminations or cracks in a structure but also evaluate and determine the extent of the damaged area. As an example, a delaminated area can, and usually does, have the appearance of a sound structure. However, a thorough inspection along with the metallic ring test will reveal flaws and unsound areas of structure.

21-48. Because of the sonic vibrations to which the B–52 aircraft is subjected, a minor scratch or defect may develop into a crack and continue propagating (spreading). Regular inspections and checks should be made to all minor scratches or defects in order to detect if any crack propagation has occurred.

21-49. Before any repair is attempted or made to a skin delaminated or cracked area, the "Damage Evaluation Chart—Honeycomb Structure" of the technical order should be consulted. A study of the chart will indicate the type of damage, whether the damage is allowable or reparable, and the accepted method of repair that will put the weakened area back in flying condition.

21-50. The method or repair to be used on bonded honeycomb skin delaminations and cracked areas depends largely on the classification of the damage. You may repair damage 1 inch or less in length or diameter by the "Potted Compound Repair" method, after which you must apply a glass cloth overlay to insure weather tightness. The glass fabric cloth overlay method will also be applied to skin delaminations and cracks larger than 1 inch in length or diameter.

21-51. Apply potted compound repairs to skin delaminations and cracks in the same manner as given in the specific aircraft technical order.

21-52. Prepare the damaged areas requiring the glass fabric cloth overlay repair by cleaning the surfaces, removing the damaged areas using a template with router equipment, and cleaning out the damage and surrounding area. After the damaged area has been completely removed and cleaned, the fillers and overlays are prepared (see fig. 60). Two layers of fiberglass cloth, number 181, impregnated with fiberglass bonding adhesive are used as filler and overlay material. The filler layers are cut 1/16 inch smaller in diameter than the damage cutout. Before a laminated glass cloth overlay is applied to a repair area, the faying surface must be cleaned until no trace of foreign materials exists. A thin and continuous film of adhesive primer EC–776R is applied to the faying surface and must be allowed to dry at either room temperature or the temperature may be accelerated by the use of heat at a recommended temperature. Then, the overlays are placed evenly over the repair area, extending at least 1½ inches beyond the edge of the damaged cutout. As an alternate to this repair procedure, three layers of fiberglass cloth, number 128, may be substituted for the filler and overlay layers. Then the repair is cured, tested, and surface finished.

21-53. **Repair of Transition Area.** The B–52 and KC–135 bonded honeycomb panels are constructed of a coupler and upper and lower skin, sectioned into bays of honeycomb core material. They are of a crushed or formed ring edge design. The edge section of a bay area in which the honeycomb structure joins the laminated edge of the panel or section is known as the transition area. Effective repairs to the transition

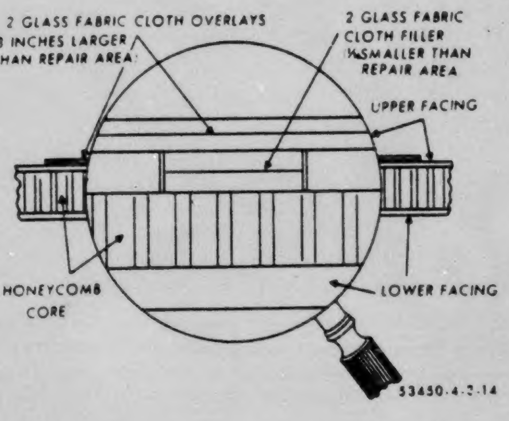


Figure 60. Magnified view of a glass fiber cloth filler and overlay.

484

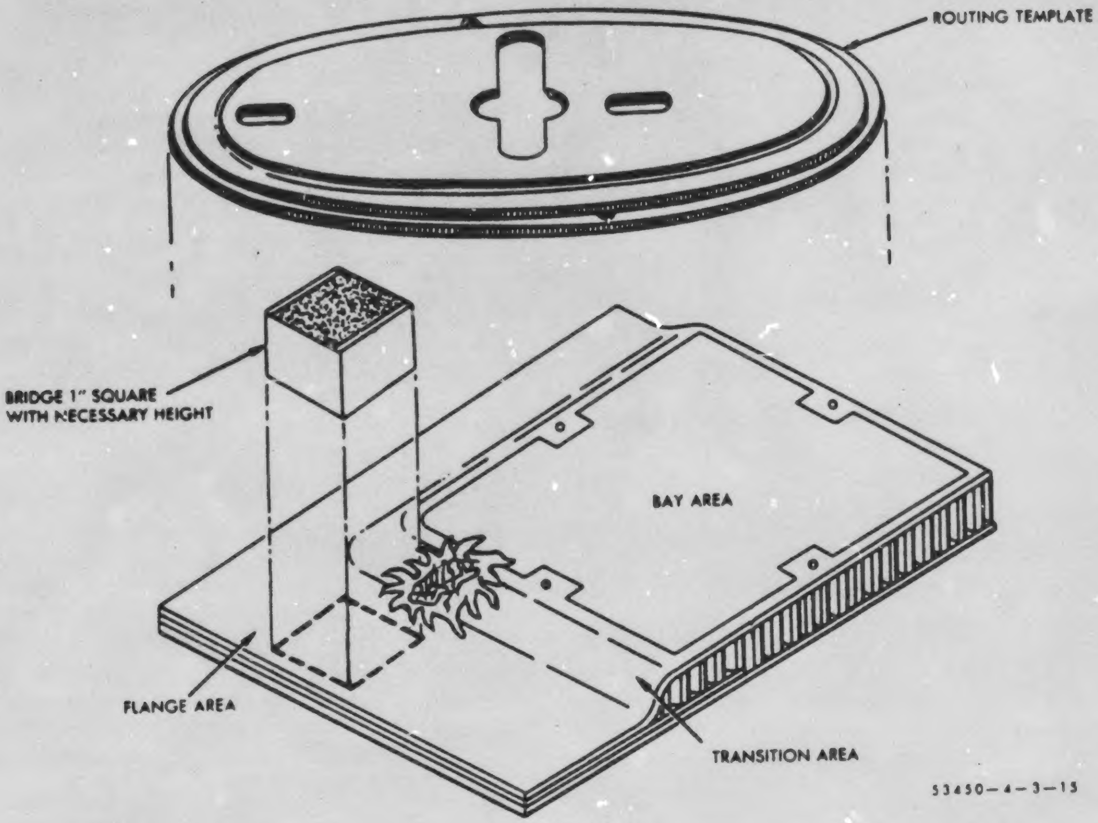


Figure 61. Routing template bridged over transition area.

areas are particularly essential because of local transference of the stresses. You should consult the applicable section of the -3 technical order for making repairs on a specific type of aircraft.

21-54. The repair to a damaged panel transition area is basically the same as any other bonded honeycomb skin and core repair. The differences you will find are in the process used in the removal of the damaged area, preparation and application of the repair core plug, and in the glass-cloth laminates or overlays.

21-55. The techniques involved in the preparation for the removal of a damaged panel transition area are similar to those you have previously studied. The only exception is that the routing template must be bridged on one edge (see fig. 61). This is necessary because of the construction features of bonded honeycomb panels and their bays (see fig. 62). The bridge consists of a wooden block, 1 inch square—the necessary height required to support and prevent the routing template from tilting or rocking during the routing operations. The routing template must be bridged in this manner to serve as a guide to the repairman so that he will make the cutout of the damaged area exactly parallel with and perpendicular to the surface. This simplifies the fitting of the repair core plug.

21-56. The preparation of the repair materials, assembly, and curing of the core plug are the same as those used for bonded honeycomb skin and core repairs. However, because of the shape and contour of the transition area (especially at the corners of a bay), special attention must be given to the cutting and shaping of the glass fabric honeycomb core material to insure that it will fit properly where the repair core plug is needed. In this repair, four layers of impregnated glass cloth (number 181) are required. The preference for number 181 cloth is due to its flexibility and ease of application, particularly when the repair is being made to a corner of a bay where a compound (double) contour is encountered.

21-57. **Tapered Trailing Edge Repair.** As we have already pointed out, damage to the trailing edge of an assembly is one of the more common damages that you will encounter in the repair of bonded honeycomb structures. Most instances of damage occur at the extreme edges where the upper and lower facings meet, the damage extending into the core material (see fig. 63). Consult the applicable section of the -3 technical order for repairs on a specific type aircraft.

21-58. A typical tapered, double-face repair has been developed for this particular type of damage. Two typical damage cutouts have also been developed and will be used in these repairs. As an example, if an inspection reveals that a damage is concentrated in one area, a half circle cutout may be used. If the damage extends along the trailing edge, yet not too far into the core material, a rectangular cutout with a minimum corner radius of 1 inch may be used (see fig. 64).

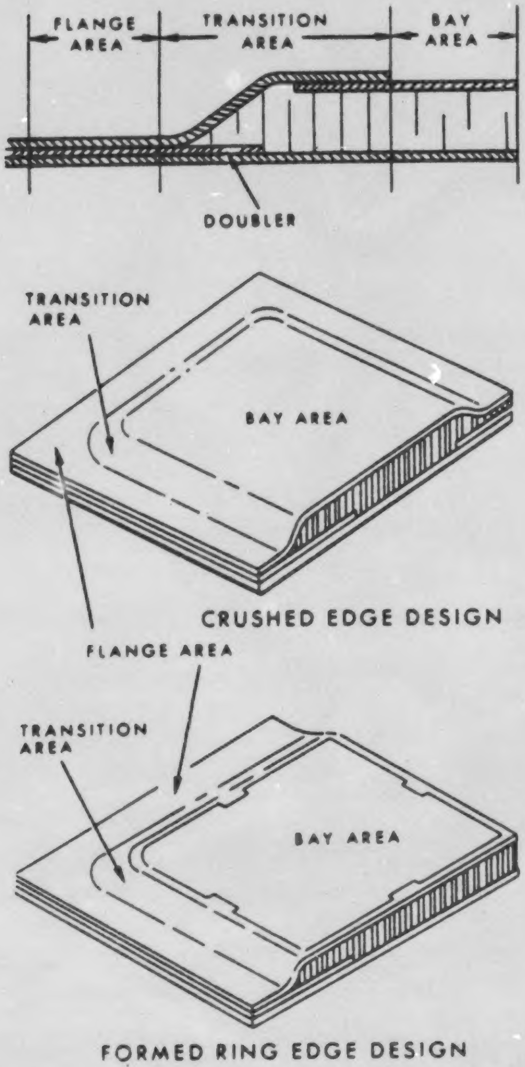


Figure 62. Typical bonded honeycomb panel bay construction.

21-59. The manner in which damages normally occur to the trailing edges of honeycomb panels or sections makes adjoining areas susceptible to delamination; therefore the adjoining areas should be closely inspected to insure a true evaluation of the damage. Any delaminations detected will be considered as part of the damage and will be repaired accordingly. Prior to any repairs to a damaged trailing edge of a honeycomb panel or section, consult the "Damage Evaluation Chart—Honeycomb Structure" in the applicable -3 technical order for that particular aircraft.

21-60. One of the more important factors that will help you to complete an acceptable repair is cleanliness. When preparing a damaged area for repair, you must insure that the adjoining areas are free of all foreign matter. The surface area extending several inches from the edge of the damage must be clean. This is done to provide a clean surface for the adhesion of the double-backed tape, used to hold the routing template in place and to insure bonding of the adhesive.

21-61. When the extent of damage has been determined, a routing template of a desired shape and size is selected. It should be of a size and shape that would permit the smallest damage cutout possible, yet allow for the complete removal of all the damaged area. The template may be of a multitype design or one manufactured locally. The routing operation is a simple task, similar to repairs already studied.

21-62. A core plug for the tapered trailing edge repair is prepared from a piece of $\frac{3}{16}$-inch cell size class fabric honeycomb core material. It is cut and sanded to the shape required to match the taper of the repair area within a tolerance of ±.010 inch. The only exception to this tolerance is that the core plug is cut shorter (¼ to ⅜ inch at the extreme tapered tip. This permits a buildup of the adhesive at the tip of the trailing edge in order to form the shape of the original design.

21-63. Before inserting the core plug in the damage cutout, be sure to "butter" all contacting (faying) surfaces of the core plug and the edges of the cutout with an application of the potting compound. A pressure jig is attached to the lower surface of the repair area to hold the core plug in place until it has been allowed to cure at room temperature for 30 to 40 minutes. The curing stabilizes the core plug and permits the removal of all extra support so that you may complete the job.

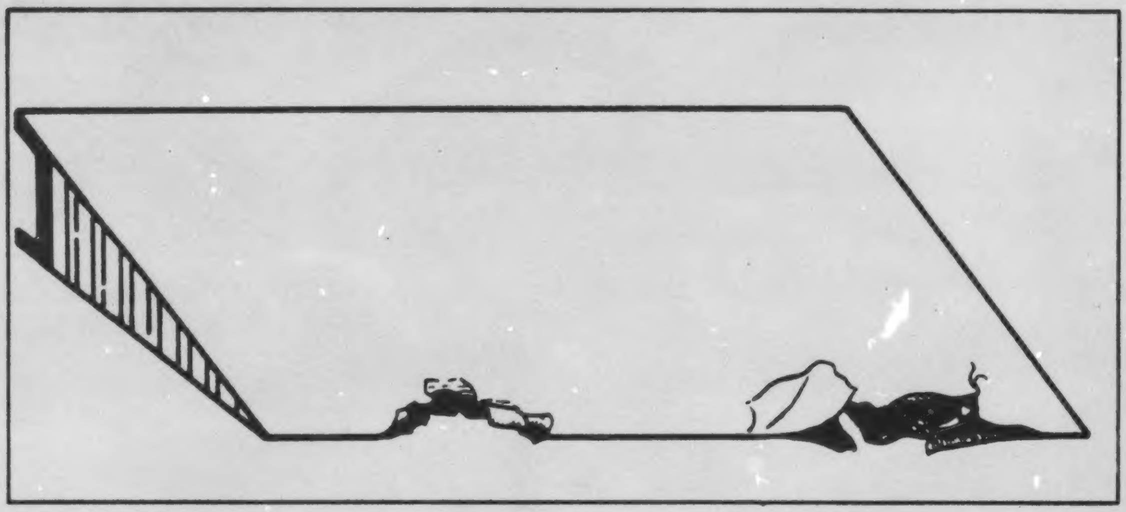


Figure 63. Typical trailing edge damage.

21-64. Before the repair area is allowed to cure, remove the excessive potting compound with a plastic scraper. Then reclean the area with MEK.

21-65. Glass cloth overlays for the tapered trailing edge repair are cut either of number 181 fiberglass or its alternate, number 128, and then impregnated with bonding adhesive. The pieces are cut at least 3 inches larger than the repair area. This allows for the required minimum overlap of the overlay—that is, 1½ inches beyond the edge of the damage cutout.

21-66. Two layers of impregnated number 181 cloth (three if number 128 is used) are used as overlays for each surface of the repair. The first overlay is fastened to the lower surface of the repair and held in place with a polyethylene film covered sheet of aluminum which acts as a pressure jig. For this type of repair, the pressure jig is made to extend approximately 2 inches beyond the trailing edge, thus providing space for the buildup of the adhesive, an excessive deposit of which is necessary to fill up the trailing edge tip to its original shape and thickness.

21-67. After the overlay for the lower surface of the repair is secured in place, the second overlay is evenly applied to the upper surface. The edge of the repair should be checked at this

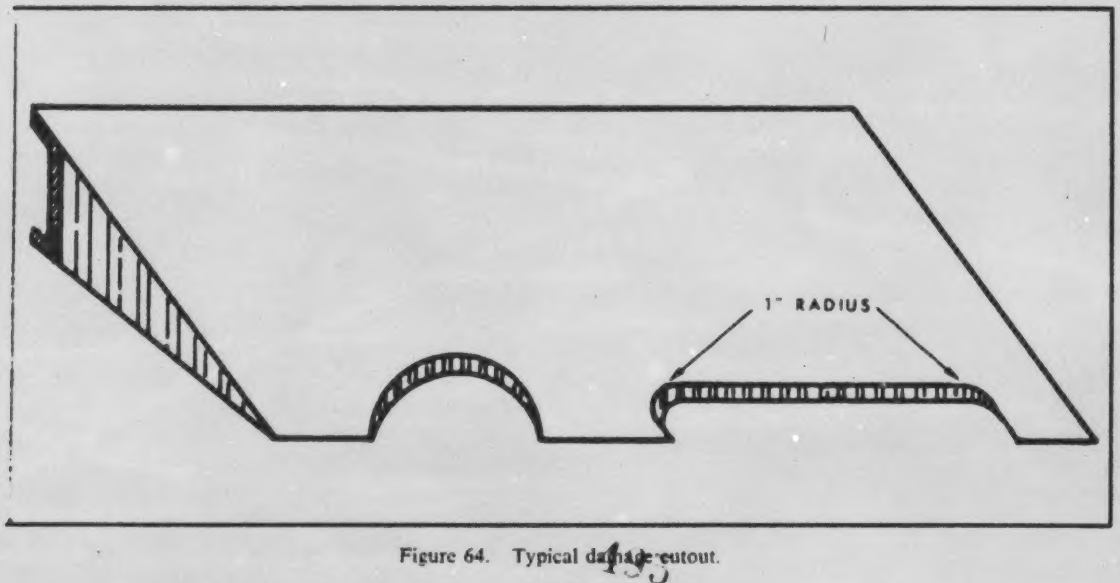


Figure 64. Typical damage cutout.

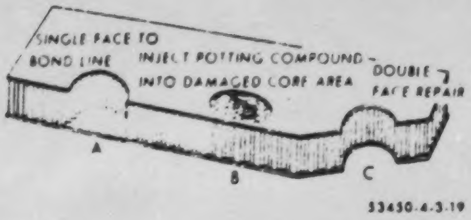

SINGLE FACE TO
BOND LINE
INJECT POTTING COMPOUND
INTO DAMAGED CORE AREA
DOUBLE
FACE REPAIR
A
B
C
53450-4-3-19

Figure 65. Cross sectional view of typical damage cutout.

point to make sure that a sufficient amount of adhesive has been deposited to build up the trailing edge. Place a sheet of polyethylene film, slightly larger than the overlay, over the upper overlay to allow for an even removal of the excess adhesive and of air bubbles. In this type of repair, the adhesive is swept out toward the edge of the repair, thus aiding in the buildup of the trailing edge area. Care must be taken during this operation to shape the repair so that it is comparable to the original design, shape, and thickness of the honeycomb structure being repaired.

21-68. Again let us emphasize that to get a perfect adhesion of the glass cloth overlays to the repair area, all surrounding (faying) surfaces must be thoroughly cleaned until no trace of dirt, surface coating, or foreign matter appears. After the area has been completely cleaned and dried, a thin and continuous coating of adhesive primer EC-776R is applied to the faying surfaces of the repair area. The adhesive primer must be allowed to dry. This may be completed at room temperature, or the process may be accelerated at a recommended elevated temperature.

21-69. **Bonded Honeycomb Skin and Core Repair.** Presently, two acceptable methods of repair are being applied to the damaged skin and core materials of the B-52 bonded honeycomb panels or structures. One is the potted compound repair and the other is the laminated glass fabric cloth overlay. For repairs on a specific type aircraft, always refer to the applicable section of the -3 technical order. You will find that the differences in the two repair methods lie in the manner of removing the damaged area; preparation and application of the repair materials and finishing of the completed repair.

21-70. The three types of repairs that may be used in cases of damage occurring to the honeycomb skin and core materials of the B-52 aircraft are:

(1) Single-face repair with damage extending partially through the core material.

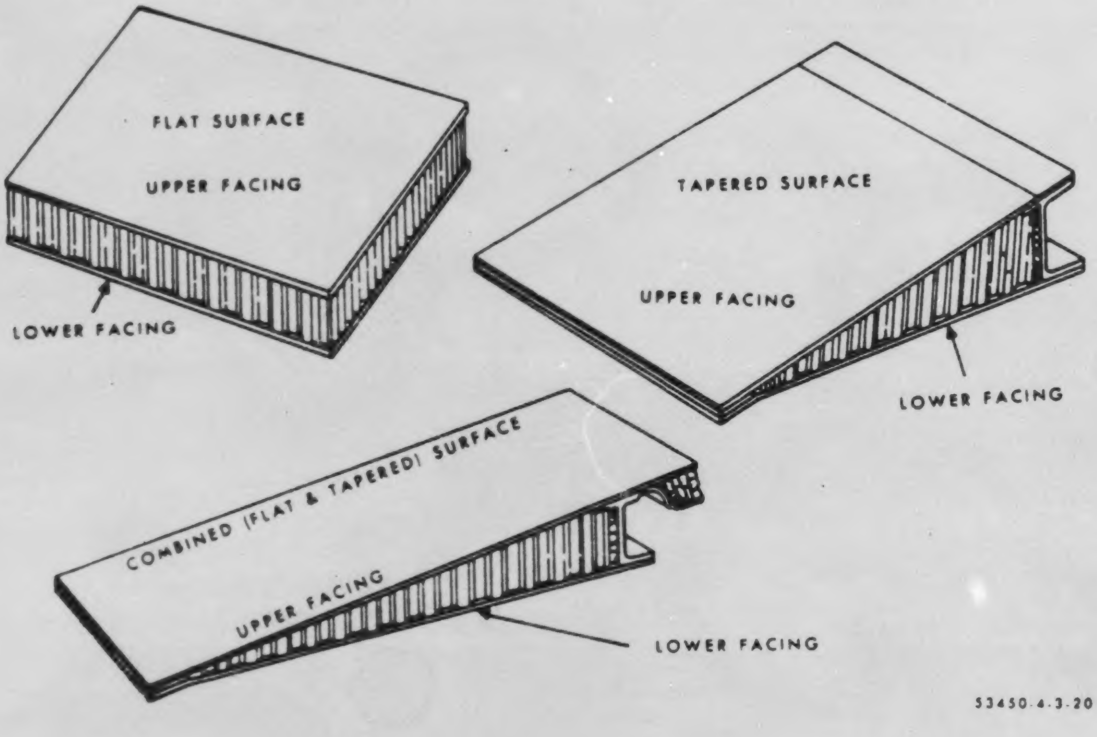

FLAT SURFACE
UPPER FACING
LOWER FACING
TAPERED SURFACE
UPPER FACING
LOWER FACING
COMBINED (FLAT & TAPERED) SURFACE
UPPER FACING
LOWER FACING
53450-4-3-20

Figure 66. Surface designs of bonded honeycomb panels.

(2) Single-face repair with damage extending through the core material and to the bond line of the opposite facing.

(3) Double-face repair with damage extending through both (upper and lower) facings and core material.

Figure 65 illustrates a cross sectional view of a damage cutout typical for each of the three repairs.

21-71. Inspection and evaluation data may be found in the "Damage Evaluation Chart—Honeycomb Structure" of the particular aircraft technical order. Special attention should be given to the damaged areas during the inspections in order to evaluate the extent (depth and length) of the damage. This is necessary to assure that an absolute minimum of material is removed from the damaged area during the routing operations.

21-72. Before any repair is made to a damaged bonded honeycomb panel or section, a surface area of several inches around the damage must be thoroughly cleaned. This is necessary to attach and secure the templates or wedge blocks to the repair area with a double-backed tape. The area must be thoroughly clean of all foreign matter to insure a perfect adhesion of the overlay repair materials.

21-73. A high-speed router in conjunction with a router support assembly, metal cutting mill bit, and template will be used in the removal of the damaged area. The techniques used in the removal of a damaged honeycomb skin and core material may differ from one repair to another. This depends largely on the construction features of the bonded honeycomb panels, which are primarily of a flat, tapered, or combined (flat and tapered) design (see fig. 66). The location of the damaged area must be considered—that is, whether the damage occurred on the upper or lower side of the panel. Another factor that must be considered is that the honeycomb core is always installed within the panels with the cells perpendicular to the lower surface. The preparation for the removal of a damaged area located on a flat or lower surface of a bonded honeycomb panel is a simple routing operation.

21-74. The procedure for the removal of a damaged area located on a tapered upper surface of a panel is somewhat different than that required for damage removal located on a flat or lower surface where the honeycomb core cells are always perpendicular to the lower surface of the panel. Therefore, prior to the routing of a damaged area of an upper tapered surface, the routing template must be bridged over the repair area. This is done in such a manner that the routing template will be perpendicular to the core cells and parallel to the lower facings (fig. 67). The bridge consists of two wedge blocks made of wood or other suitable material, at least 6 inches long, approximately 2 inches wide, and tapered to the same degree of angle as that of the panel.

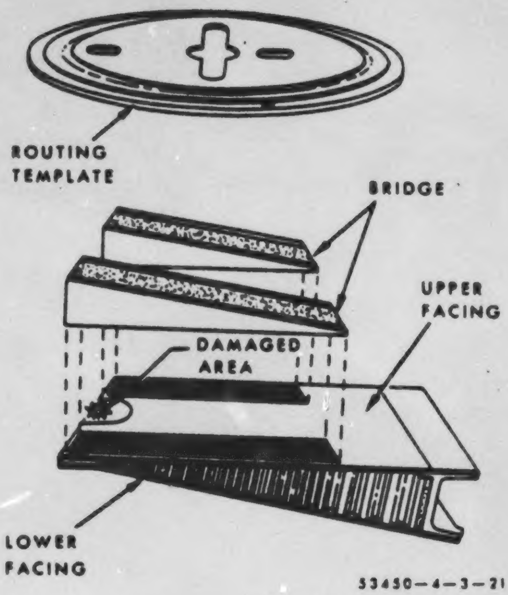


Figure 67. Wedge blocks and application.

21-75. A core plug is cut slightly larger than the desired thickness and shape from ($\frac{3}{16}$-inch cell size) fiberglass honeycomb core material. It is sanded to the correct shape and thickness with a belt or disc sander to a tolerance of ±0.010 inch. Before a core plug is inserted or assembled into the repair area, all contacting (faying) side surfaces of the core plug and the repair area must be "buttered" with a potting compound. In addition, for single-face repairs the potting compound may be injected into the damaged core area. This insures a sound bonding effect of the core plug repair area. After the core plug has been properly installed in the repair area, the excessive potting compound is removed with a plastic scraper and the surface area thoroughly cleaned with MEK. The repair should be cured for a period of at least ½ to 1 hour. In this way you make sure the core plug is firmly in place before any further repair steps are taken.

21-76. A laminated glass cloth overlay consists of two layers of fiberglass cloth, number 181 (three layers if number 128 is used), impregnated with fiberglass bonding adhesive and sandwiched between two sheets of polyethylene film. The glass cloth layers and sheets of polyethylene film are cut larger (approximately 4 inches) than the damage cutout. This is to accommodate the cutting of the laminated overlay to correct size, allowing for the required minimum overlay of at least 1½ inches beyond the edge of the damage cutout. After the area has been thoroughly cleaned and dried, a thin and continuous film of adhesive primer EC-776R is applied to the faying surfaces of the area. The adhesive primer must be allowed to dry at either room temperature or may be accelerated by heat at a recommended temperature.

22. Inspection of Completed Repair

22-1. After completion of any repair, perform a final inspection to determine whether repairs have been made in accordance with requirements and specifications listed in the appropriate aircraft technical manual of structural repair. The inspections which you perform are not to be confused with those made by an authorized inspector; you simply check points to determine that the repairs are properly made before the aircraft is declared in serviceable condition. These final checks often turn up discrepancies which were overlooked and might cause other damage. The most important factors in repair and those of which you should be constantly conscious are:

- Maintaining original strength.
- Keeping weight to a minimum.
- Maintaining original contour.
- Preventing corrosion.

These inspections can be embarrassing or they can be pleasant; how you feel about them is mostly up to you. If you are alert and apply yourself, there will be few, if any, defects in your work and you can be proud of the job. Your supervisor will appreciate it too, for you will have provided him with more time to devote to his other duties.

22-2. The repair of metal bonded honeycomb assemblies requires the airframe repairman to use an entirely new and a scientific approach when repairing modern high performance aircraft. New skills, techniques, and methods must be learned and used in mixing, applying, and curing adhesives or potting compounds.

22-3. Remember, bonded honeycomb repairs may appear to be similar on different aircraft, but never attempt any honeycomb repair until you have carefully consulted the applicable -3 technical order for a specific type aircraft.

22-4. In chapter 4 we discuss cable and plumbing (tubing) construction, use, damage, and repairs. It is not a new area, but its application to high-speed performance aircraft is different because higher pressures will be used in plumbing and the control cables are more sensitive. The knowledge you now possess in this area will aid you in learning the materials concerned in the following chapter.

CHAPTER 4

Aircraft Cable and Plumbing Repair

WHEN AN AIRCRAFT has an engine failure or structural damage in midair, the pilot has a good chance of bringing the plane in safely. Failures in hydraulic lines or control cables, however, are much more serious, and the pilot had better start thinking of his parachute.

2. A part of the airframe repairman's duties includes the repair or replacement of plumbing and control cables. Just as in the case of repairs you make on aircraft structures, all damaged plumbing lines and control cables should be restored to their original condition or as near the original condition as possible. Very often the job calls for a replacement: but if replacements are not available, plumbing lines and control cables must be fabricated.

3. The objectives of this chapter are to explain or give the use and identification of repair materials, evaluation of damage, fabrication, and safe repair procedures by means of written data and applicable illustrations. Some of these text materials may be new, but many of them will be a review of what you have previously studied elsewhere.

4. Plumbing lines and control cables must be inspected periodically to keep them in a safe operational condition. While making repairs, always observe all safety precautions during inspection and operation of assemblies and during installation and inspection of the completed job.

23. Aircraft Cables

23-1. Cables are used on aircraft to operate and regulate control surfaces, excape hatches, life raft compartments, bomb bay doors, wheel-well doors, and engine accessories. Cables are used to tow gliders and targets; to release parachutes, bombs, and flares; to load ammunition and cargo; and to perform a number of essential maintenance functions, such as hoisting and towing.

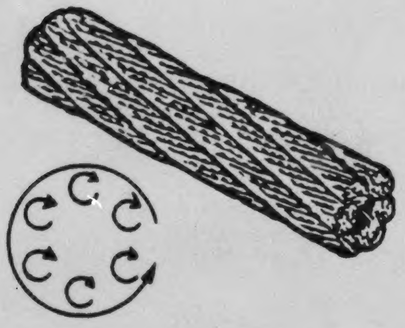
23-2. Cables in aircraft control systems have part numbers and come prefabricated to fit from turnbuckle to turnbuckle or from turnbuckle to unit. Spare cable assemblies are not always available, so you may have to duplicate damaged ones.

23-3. Many advantages are gained by the use of cables in aircraft. One of the most important is that cable failure is never abrupt but is progressive over periods of extended use. They seldom break or sever even under strains such as occur during towing or hoisting. Cables are stronger than steel rods or tubing of the same size. They flex without setting and can easily be routed around obstacles with pulleys. Cables can be installed over long distances (a necessity in bombers) without a great degree of sagging. Vibration will not cause them to work-harden, as sometimes happens when either push-pull control rods or tubing is used.

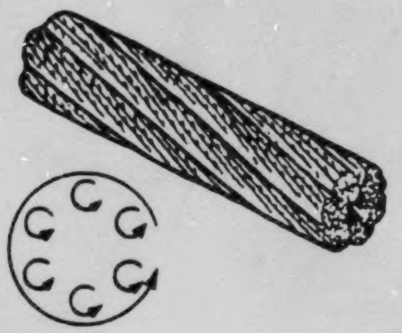
23-4. When cables are used for the operation of a unit, they must be used in pairs—one set to move the unit one direction and the other to move it in the opposite direction. In spite of the need of a second set, weight is saved because a push rod needed to create a similar movement would be considerably heavier. Since cables are used in pairs and are stretched taut, very little play is present between the actuating device and the unit. Consequently, cable-controlled units respond quickly and accurately to cockpit control movements.

23-5. **Cable Construction.** A cable is a group of wires or strands of wire twisted together to make a wire rope. The relationship of the direction of twist of each strand to another and to the cable as a whole is an important factor in its strength. If the strands are twisted in a direction opposite to the twist of strands around the center or core, the cable will not stretch or set as much as one in which all strands are twisted in the same direction.

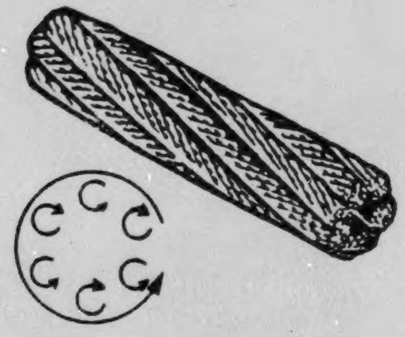
23-6. The direction of twist (in opposite direction) is most commonly used. It is called regular or ordinary lay (see fig. 68). Cables may have right regular lay or left regular lay. If the strands are twisted in the direction of the twist



RIGHT REGULAR LAY, ROPE LAY RIGHT, STRAND LAY LEFT.



RIGHT LANG LAY, ROPE LAY RIGHT, STRAND LAY RIGHT.



REVERSE LAY, ROPE LAY RIGHT OR LEFT, STRAND LAY ALTERNATELY RIGHT AND LEFT.

53450-4-4-1

Figure 68. Cable lay.

of the core, the lay is called a lang lay. There are two lang lays: right and left. Another arrangement is the twisting of all the strands either to the right or to the left about the core; this is called reverse lay.

23-7. When aircraft cables are manufactured, each strand is first formed to the spiral shape to fit the position it is to occupy in the finished cable. This process is called *performing*: cables made by such a process are said to be *preformed*. Preforming is used to obtain flexibility in the finished cables and to relieve bending and twisting stresses in the strands as they are woven into the cable. It also keeps the cable from spreading when cut.

23-8. Each strand is made of highly flexible material. Some cables are so flexible that they are classified as extra flexible; others are classed as flexible. Cables as large as 5/8 inch can be obtained in the extra flexible type or as large as 1 inch in diameter in the flexible type.

23-9. Aircraft control cables are fabricated from flexible, preformed, carbon steel wire or corrosion-resistant steel wire. The smaller corrosion-resistant steel cables are made of steel containing 17 percent chromium and 8 percent nickel. The larger cables, 5/16, 3/8, and 7/16 inch, are made of steel which contains, in addition to the chromium and nickel mentioned, not less than 1.75 percent molybdenum.

23-10. Control cables vary in size from 1/16 to 3/8 inch in diameter, as shown in figure 69. Cables 1/16 and 3/32 inch in diameter are composed of seven strands of 7 wires each and are referred to as 7 x 7 (1 WRC) cable—that is, six strands are wrapped around the center or core strand. Cables 1/8 inch in diameter and larger are made up of seven strands of 19 wires each and are referred to as 7 x 19 (1 WRC) cable (1 WRC stands for one wire rope center). Again, six strands are wrapped around the center strand.

23-11. **Damage Evaluations.** In the performance of your duties as an airframe repairman, you may have to inspect cables for broken wires, worn spots, and corrosion.

23-12. The results of tests show that the loss in cable strength from broken wires depends upon the concentration of breaks at any one point rather than the total number broken in the cable. Other tests have shown that cables may have broken wires and still be capable of carrying the designed load of the cable. At each regular inspection period, cables should be inspected for broken wires by passing a cloth along the length of the cable. Broken wires are indicated where the cloth is snagged. TO 1-1A-8 and the maintenance technical order for the specific aircraft should be consulted for limitations as to the lo-

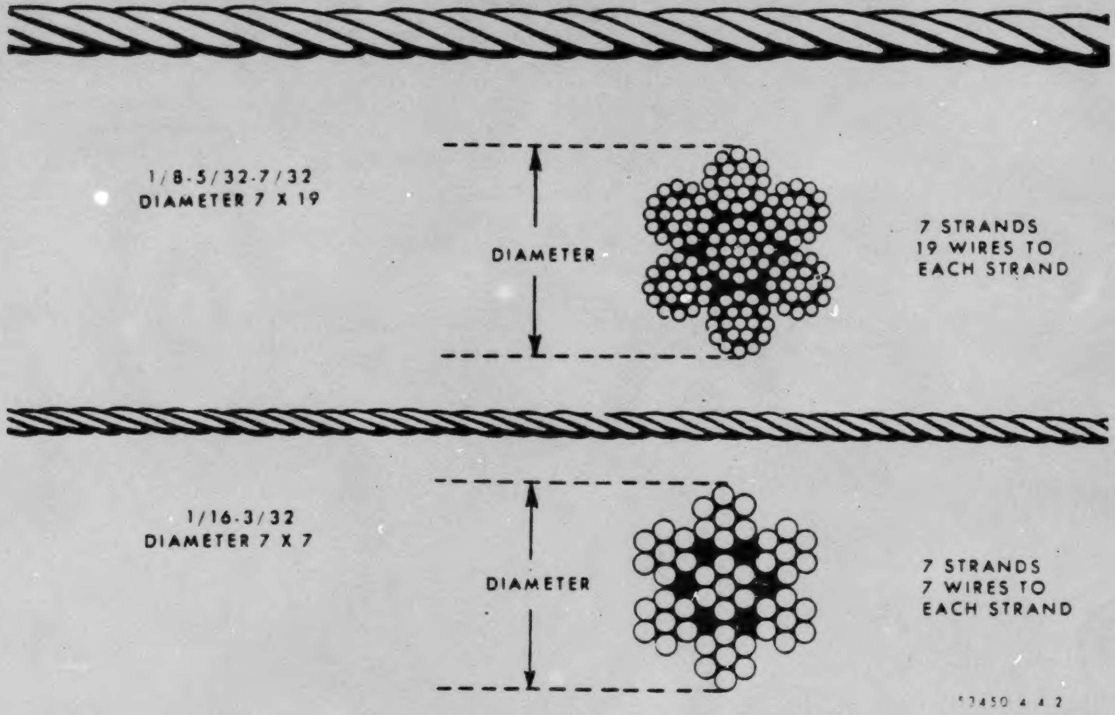


Figure 69. Measuring cable diameter.

cation and number of wires that may be broken and yet the cable remain serviceable.

23-13. Corroded cables present another reason for removal and replacement of the assemblies. The surface of cables should be inspected for corrosion. If such a condition is found, relieve the tension on the cable. Any corrosion of the interior strands of the cable constitutes failure and the cable must be replaced. If no interior corrosion is detected, remove loose rust and corrosion with a rag or brush moistened with solvent P-S-661b. Clean the cable with steel wool, but be careful not to damage it in the process. Coat the cable with an approved corrosion preventive material.

23-14. An inspection of cables may reveal worn spots in the strands. Any 7 x 7 cable having 3 wires or less per inch, or any 7 x 19 cable having 6 wires or less per inch, that is, not worn more than halfway through the wire diameter (provided no broken wires are present in worn area) is considered serviceable. One less worn wire per inch is allowed for each broken wire present in the same inch. Any cable exceeding the limits just specified should be replaced.

23-15. **Hardware.** The flight control system of an aircraft includes the movable surfaces which determine the direction and attitude of the aircraft, the devices by which the pilot manipulates these surfaces, and the linkage by which the movement is transmitted to the control surfaces. On many aircraft the linkage system consists of lengths of flexible cable, together with the various devices required to operate the system.

23-16. In a cable type control system, a number of different cable hardware items are required as well as the individual sections of cable. Such items may be classified as cable fittings and cable accessory items. You need to become familiar with these accessories and with the splicing tools used in making cable repairs and with the tension measuring instrument used after cable installation.

23-17. Cable fittings (fig. 70) include turnbuckles, thimbles, bushings, shackles, terminal fittings, and the items of hardware discussed in the following paragraphs.

23-18. A *ball type fitting* is a cable fitting in the form of a metal ball, drilled so it can be swaged onto a cable. A *shank* may protrude from one or from both ends so that the fitting may be swaged more securely. The ball may serve as a terminal or as a cable stop, or it may be fitted into notches on quadrants or drums to prevent creeping of the cable on the drum.

23-19. A *bushing* is a small pulleylike ring used in a cable loop. The outer surface is grooved to fit the cable, and the inner surface forms a smooth bearing. Bushings are usually made of corrosion-resistant steel. They are available in different thicknesses, diameters, depths of grooves, and sizes of hole to conform to the various sizes of the cables with which they are to be used.

23-20. A *clamp* is a fastening device for heavy wire cable. It consists of two metal pieces, each with two straight parallel grooves. The two pieces are placed one on each side of the standing and free ends of the cable with the cable in the grooves. The two pieces are then clamped together with bolts.

23-21. A *clevis* is a U-shaped terminal fitting by which cables may be fastened to an actuator or to a unit. A clevis pin is used at one end; the other end of the clevis is attached to the cable by soldering or swaging. (Do not confuse the clevis with the fork.) A clevis does not have the breather holes, which are a characteristic of the fork.

23-22. A *clip* is a U-shaped bolt with a clamp base and a nut that is used to clamp the free end to the standing length of the cable. Clips give a lighter and neater appearance than clamps. The number of clips to be used varies with the size of the cable. When attaching a clip, place the U over the free end and the base over the standing end of the cable.

23-23. A cable *eye* is an end or terminal fitting for connecting a cable to another fitting. It may form the end of a swaged fitting. A cable bushing can be considered an eye.

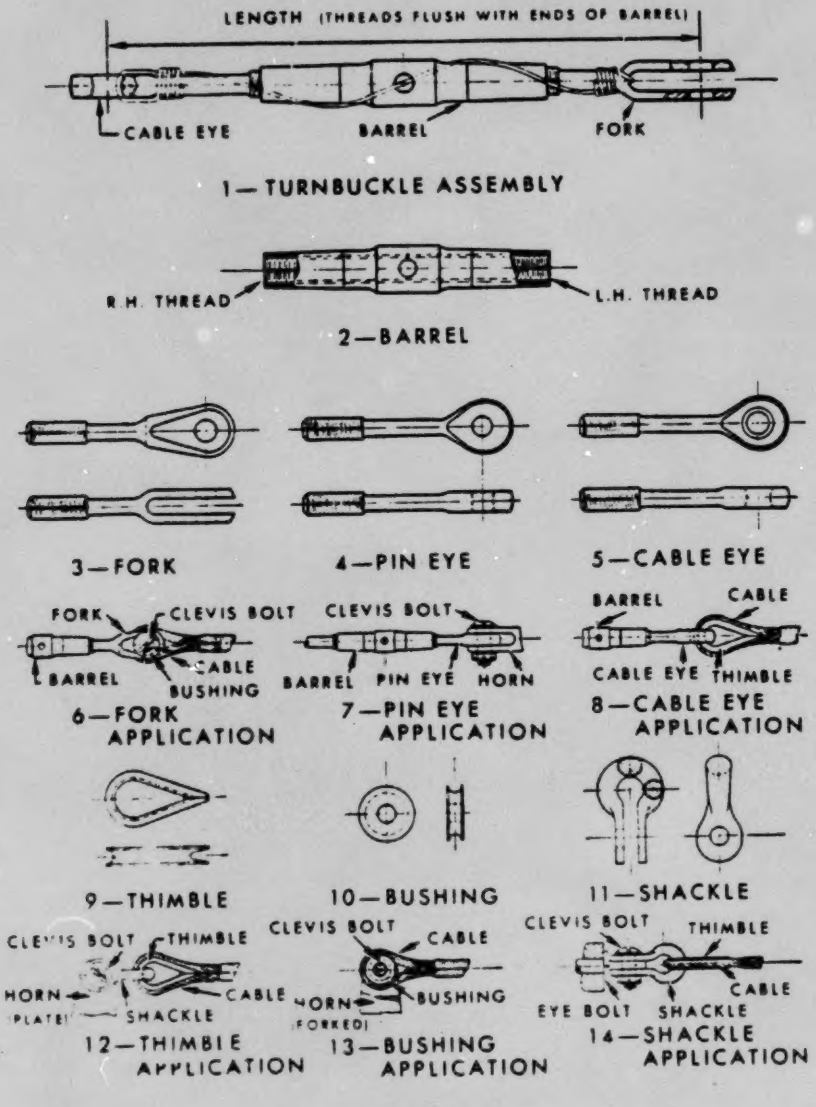

LENGTH (THREADS FLUSH WITH ENDS OF BARREL)
CABLE EYE
BARREL
FORK
1—TURNBUCKLE ASSEMBLY
R.H. THREAD
L.H. THREAD
2—BARREL
3—FORK
4—PIN EYE
5—CABLE EYE
FORK
CLEVIS BOLT
CABLE
BARREL
BUSHING
6—FORK APPLICATION
CLEVIS BOLT
BARREL
PIN EYE
HORN
7—PIN EYE APPLICATION
BARREL
CABLE
CABLE EYE
THIMBLE
8—CABLE EYE APPLICATION
9—THIMBLE
10—BUSHING
11—SHACKLE
CLEVIS BOLT
THIMBLE
HORN
(PLATE)
CABLE
SHACKLE
12—THIMBLE APPLICATION
CLEVIS BOLT
CABLE
HORN
(FORKED)
BUSHING
13—BUSHING APPLICATION
CLEVIS BOLT
THIMBLE
CABLE
EYE BOLT
SHACKLE
14—SHACKLE APPLICATION

Figure 70. Cable fittings.

23-24. A *fork* is a terminal fitting which has two prongs to fit over the mating prong of an eye.

23-25. A *shackle* is a metal loop by which cables may be attached to a unit. A shackle is usually used in connection with a loop and thimble.

23-26. A *socket* is a special kind of cable fitting. It has an opening into which a cable end can be inserted for fastening. It is equipped with a loop, bar, or fork, to which another connecting device, such as a hook, ring, or loop, can be attached.

23-27. A *stop* is a device placed on some cables to limit travel of the cable or of the control. Stops may be of the ball type, they may be rectangular fittings swaged into place, or they may consist of a tapered locking screw and nut assembly. The screw type can be moved back and forth along the cable and can be used as an adjustable stop.

23-28. A *thimble* is a pear-shaped grooved loop of thin metal around which a cable is bent for splicing. Thimbles reinforce cables and prevent chafing and sharp bending at points of attachment. Thimbles can be obtained in various sizes to accommodate various sized cables.

23-29. A *turnbuckle* is a device for joining cable ends and for adjusting cable tension. A turnbuckle assembly consists of a barrel and two connecting fittings, either forked, eye-shaped, or sleeved. The barrel is fitted with left- and right-hand threads at opposite ends; the turning of the barrel will cause both fittings to move in or out simultaneously, the cable thus being either tightened or loosened.

23-30. Various cable hardware items serve as accessories to the function of the individual cables. Some transmit motion increase or decrease cable travel distance, prevent slippage, reduce vibration in long distances of cable, and change direction of the cables. The following paragraphs explain these accessory items.

23-31. An *actuator* is a device which sets something else in motion. In cable control systems it is a casting to which cables are attached. Cable quadrants and drums located in the pilot's pedestal are actuators, since motion is transmitted to the cables by them.

23-32. A *bellcrank* is used chiefly for changing cable direction or for increasing or decreasing cable travel distance. A bellcrank may often be placed at the end of a cable to serve as an actuator of a unit.

23-33. A *cable drum* is a cylindrical casting with several grooves about which a cable can be wound so there will be no cable slippage. Drums are placed at points where a very slow and sure motion is desired. The adjustment mechanism for trimming of tabs is a good example of the use of a cable drum.

23-34. A *fair-lead* is a small fixture, usually made of plastic material with one or several holes through which cables may pass. It is used to prevent cables from coming in contact with structural parts of the aircraft and to reduce vibration in long stretches of cable. Whenever cables pass through pressurized compartments, fair-leads must be airtight. In such instances pressure seals are used as fair-leads.

23-35. A *pulley* is a grooved wheel, often made of plastic material, which supplies a rolling bearing at a point where the cable changes direction.

23-36. A *quadrant* is a casting to which cables are attached for actuating purposes. It is usually a fractional part of an actuating pulley (consequently, the term quadrant). The quadrant is actuated by an attached lever, and this action transmits motion through the cable to a drum or an actuating pulley, which in turn causes movement in the unit.

23-37. A *sheave* is a large pulley, usually made of metal, which performs functions similar to those of bellcranks (that is, reducing or increasing travel distance and changing direction of cables).

23-38. There may be times when cable replacements are not available and you have to fabricate them. The splicing tools you would use are described below.

23-39. *Marlin spikes* are awllike handtools, made of iron or steel, with tapered points. They are used for separating cable strands during the cable-splicing operation.

23-40. A block of lead, hardwood, or the like, on which the tucked strands of a cable can be lightly hammered during splicing is called a *pounding block*. This pounding process presses the strands together firmly, making a neat and compact splice. The block is sometimes called an anvil.

23-41. A *splicing vise* is a holding device which clamps the cable close to the thimble or bushing and holds the assembly securely during the splicing operation.

23-42. **Tensiometer.** A tensiometer (fig. 71) is an instrument which measures the tension in a stretched or loaded cable. It is not a precision instrument and is inaccurate for cable tensions under 30 pounds. You should refer to TO 1-1A-8, *Aircraft Structural Hardware*, and to the maintenance manuals for the specific aircraft to find the information on procedures and cable tensions.

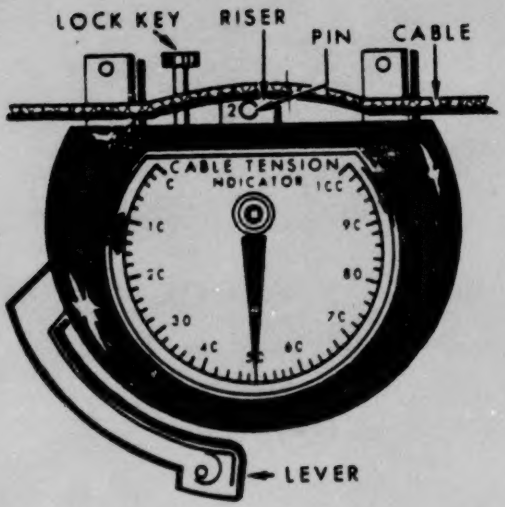


Figure 71. Cable tensiometer.

23-43. **Fabrication.** When needed cable assemblies are not available as replacement items, they will have to be fabricated. Should immediate replacement be required, certain alternate cable fittings and processes may be substituted for the original items. Replacements for swaged cables may be prepared by using cable bushings and eye splices and the proper combination of turnbuckles and clevises.

23-44. Eye type swaged terminals may be replaced by a cable bushing in an eye splice. Clevis type terminals may be replaced by cables thimbles in conjunction with an eye splice and a shackle. Cables having a diameter of 3/32 inch and over may be woven-spliced by the 5-tuck method, and cables of 1/16-inch diameter may be wrap-soldered. Whenever selecting hardware for cable assemblies, be sure to follow technical order recommendations.

23-45. *Cable cutting.* Cables may be cut by any cutting method except a torch. When cutting cable, you must try to make a sharp square cut without greatly disturbing the strand group. The cable cutting machine (shown in fig. 72) is used primarily for cutting 3/32-, 5/32-, and 7/32-inch cables. Larger cables should be cut with a radiac (a thin abrasive wheel which revolves at high speed).

23-46. Smaller cables can be cut satisfactorily with wire nippers, heavy-duty diagonal cutters, or with side cutters. There is the possibility of a cable unraveling or fraying when it is cut. To avoid this, sweat-solder or wrap a strip of masking or friction tape around the cable so that when it is cut, half of the soldered or taped width will remain on each end of the cut cable. The solder or tape aids in making a clean cut. A cold chisel, properly used in conjunction with a soft metal block, will usually give satisfactory results when you are cutting cable.

23-47. *Swaging.* When applied properly, the swaged terminal forms a bond stronger than the cable. This factor, along with the compactness and ease of manufacture and repair, accounts for the wide acceptance of this fitting by the aircraft industry and the Air Force. The terminals are manufactured in sizes to fit the various size cable used on aircraft; furthermore, a terminal cannot be used for any size cable except that for which it is manufactured.

23-48. The terminals are attached to the cable by a forming or cold-working process which reduces the sleeve diameter of the terminal. This cold working with a swaging machine presses the terminal sleeve with sufficient pressure to force the metal to form around the wires of the cable. This operation requires a tremendous force at the point of application.

23-49. The hand-swaging tool is commonly used for repair work. The pressure exerted by the dies rolls out the metal similar to a rolling pin rolling out dough. Since cables are manufactured with the terminal connectors to fit at specific distances, you must consider this elongation of the terminal when attaching the fitting; otherwise, the cable will not be of the correct length when finished.

23-50. Always use swaged terminals if at all possible. When swaging a terminal, cut the cable to the required length (allow for the fitting elongation). Before inserting the cable end into the terminal for swaging, be sure that the cable has been cut square and clean and that all

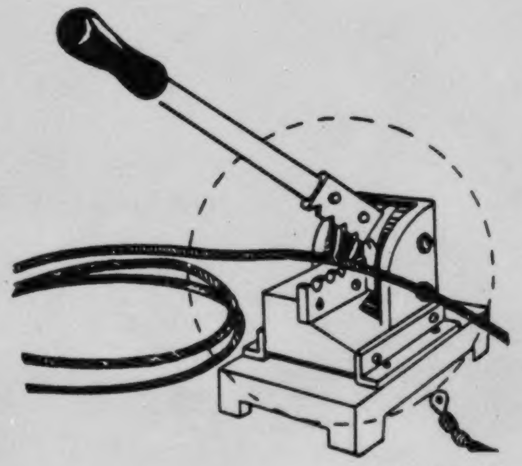


Figure 72. Cable cutting machine.

strands remain in a compact group. Dip the cable end into some light oil, such as number 10 SAE, and then insert the lubricated end into the terminal to a depth of approximately one-half of the barrel's length.

23-51. Bend the cable toward the terminal to about a 45° angle; then, straighten the cable back to normal, and push it the remaining distance into the terminal barrel. Kinking the cable in this manner provides enough fiction to hold the terminal in place until the swaging operation can be performed. Bending the cable also tends to separate the strands inside the barrel and reduces the strain placed on them by swaging.

23-52. When swaging terminals, install the proper size dies in the swaging machine or hand swager for the size of the terminal being used. Insert the cable end and terminal into the swaging machine and perform the swaging operation. After swaging is completed, measure the outside diameter of the terminal barrel to determine if it has been swaged sufficiently. If the terminal is bent more than the allowable ½°, place it securely in a vise and straighten it with a mallet or with moderate pressure fom the jaws of the vise.

23-53. If swaged terminals are to be used on each end of the cable, both ends of the cable must be swaged. Be sure that all additional fittings and accessories, such as cable stops and fair-leads, are slipped onto the cable first and in the proper sequence before swaging the other end.

23-54. *Sweat-soldering terminals.* Sweat-soldered terminals are used on lightly loaded cables only and on replacement cables only if this process was used in the original installation. Sweat-soldered terminals differ from swaged terminals in that there are breather holes in the barrel of the soldered type. These breather holes allow the molten solder to permeate the strands and the lower part of the barrel without interference from air bubbles.

23-55. During the soldering process, place the terminal in a clamping device, barrel up. The clamping device should have jaws of fiber or some other material that will not transmit heat readily. With a hot soldering iron (usually made of copper) apply heat to the barrel.

23-56. When the terminal is thoroughly heated, insert a small amount of soldering flux into the barrel. Stearic acid, a suitable mixture of stearic acid and resin, or resin dissolved in alcohol may be used as flux. *Never use a corrosive flux such as muriatic acid on aircraft cables.*

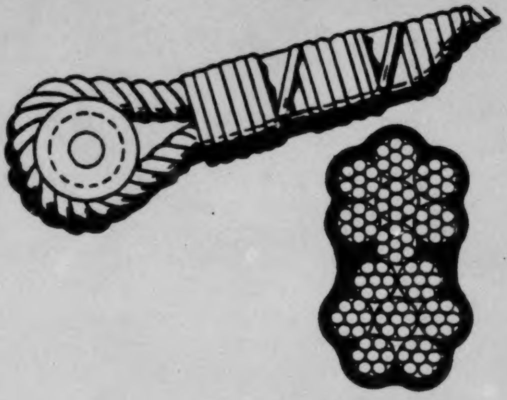


Figure 73. Wrap-soldered splice.

23-57. Apply soldering flux to the end of the cable before inserting it into the barrel of the terminal. On clevis type terminals, allow the cable to extend through the barrel a short distance, free the end strands to allow them to fray, then pull the cable back into the barrel until the cable end is flush with the clevis.

23-58. Apply tin-lead solder around the cable at the terminal opening. By sweat-soldering, draw solder in at the cable barrel opening until solder appears at the opposite end of the barrel (as in clevis type cable), or until the solder fills each breather hold. Form a bead around the cable at the terminal opening. Then allow the solder to air cool. *Do not quench.*

23-59. *Wrap-soldering terminals.* The wrap-solder splice (fig. 73) may be used for the fabrication of end fittings on cables of 1/16-inch diameter only. You may replace an eye bushing and a clevis type fitting with a cable thimble and shackle (see pars. 23-21 and 23-23).

23-60. Arrange the cable and the fittings, allowing approximately 2¼ inches of free end. When wrapping a splice and using a thimble and shackle, be sure to place the shackle through the thimble before beginning the splice, as this cannot easily be done after the splice is completed. Clamp the assembly in a splicing jig and secure it in a vise.

23-61. When starting a wrap-solder splice, press the free end and the standing length of the cable together tightly. Start the wrap as close as practical to the end fitting, using a single layer of number 20 zinc-coated steel wire. Leave spaces approximately ⅛ inch between every ½ inch wrapping. Allow the wrapping to extend ¼ inch beyond the free end of this splice. During the wrapping operation, be sure you keep the free length parallel to the standing length and the standing length from twisting.

23-62. Remove the splice from the cable jig and apply a noncorrosive flux to the entire splice. Carefully sweat the solder into the cable through the wrapping. Apply solder until the wrapped section is barely visible. Allow the solder to air cool. Using hot water, wash away all soldering flux from the splice and adjacent cable. Dry the splice and apply a rust or corrosion preventive solution of the correct specification. Carefully inspect the splice. A wrap-soldered splice easily bent with the fingers is unsatisfactory, for it indicates poor solder penetration. The presence of cracks in the solder between the wrapping sections is an indication of slippage in the splice.

23-63. Before replacing a clevis type terminal with a thimble and shackle, make sure that there will be sufficient room and clearance near the unit for its assembly. If there is not enough room, make an eye splice with a bushing and use it in conjunction with a turnbuckle assembly.

23-64. *Woven-spliced terminals.* If facilities are limited and immediate replacement of a cable is imperative, you may substitute the five-tuck woven-spliced terminal, using a bushing or a cable thimble and shackle, for a swaged terminal. Because of various restrictions such as fair-leads, cutouts, and pulleys, the cable splice may have to be made in the aircraft. When splicing a cable by this method, first, remove the cable from the aircraft; next, anneal the cable strands by applying a torch flame for a distance of 1 inch from the tip then proceed by the steps shown in figure 74.

23-65. In addition to the illustrated steps, there are some intermediate processes not illustrated which must be performed at various stages of the splicing operation. They are as follows:

(1) After completing the first tuck (shown in the second example of fig. 74), pull the free ends taut with pliers. Pull in the direction of the bushing. Do this after you make each tuck.

(2) After pulling the free ends taut, start with the free strand indicated by the number 1 and work in a counterclockwise direction, as viewed from the bushing end, tucking each free strand under every other standing strand as shown.

(3) After completion of the third complete tuck, divide in half the number of wires in each free strand. There are 7 wires making up each strand. Therefore, you would select 4 wires to retain and cut off the 3 wires with side cutters or a pair of diagonals. With the remaining 4 wires of each strand, completely make the fourth tuck in the same manner as the previous three tucks.

(4) After completion of the fourth tuck, again halve the remaining wires, now numbering only 4. Cut off the extra wires as before, and with the remaining 2 wires make the fifth and final tuck as you did the other four tucks.

(5) Closely cut off all the protruding strands, using diagonals or a similar tool, and place the splice on a pounding block. Pound the splice moderately with a wooden or rawhide mallet until it is fairly smooth and has an even contour.

(6) Serve the splice with waxed linen cord, as shown in example four of figure 74. Apply two coats of shellac, allowing 2 hours to elapse between coats.

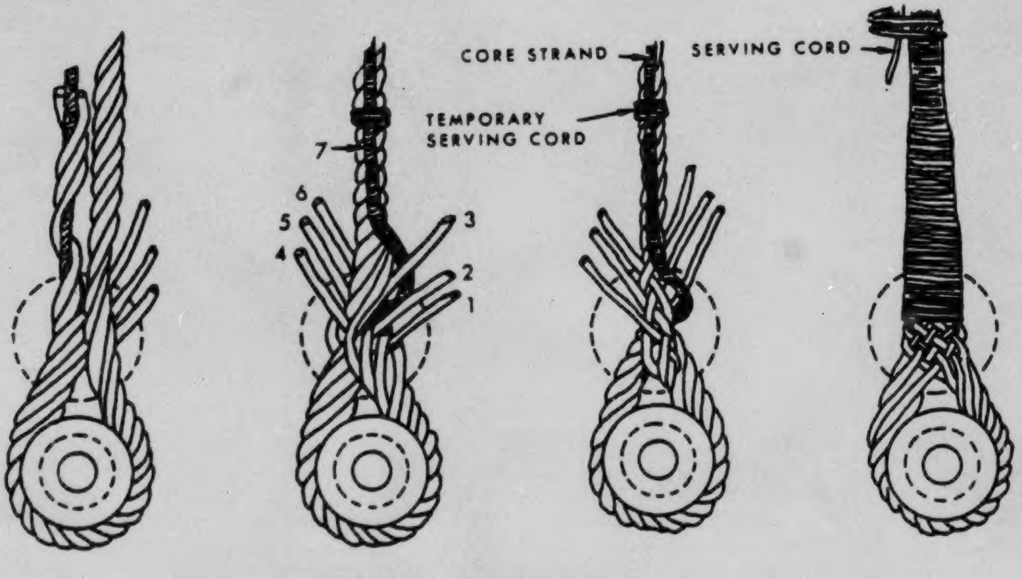


Figure 74. Steps in splicing.

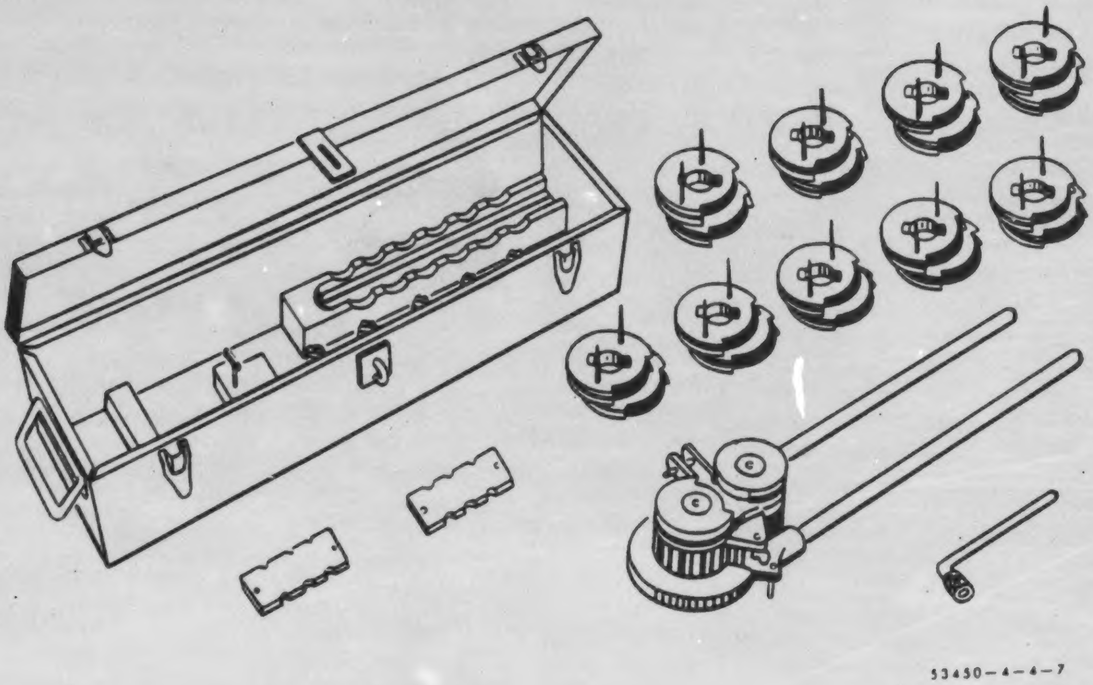


Figure 75. Kearney swaging machine.

(7) After the cable assembly is fabricated, its minimum strength should be tested with a tensile tester. Finally, if the cable is carbon steel, it must be treated with a rust-preventive compound.

23-66. **Kearney Swaging Machine.** This machine (fig. 75) comes in a case and has interchangeable dies or rollers. It can be assembled to swage terminals on all cable sizes up to ¼ inch that are commonly used in aircraft.

23-67. A set of dies consists of two rollers, and each set is clearly marked for a specific cable size. When swaging terminals with this machine, be very careful to check the size of the cable, terminal, and dies to make sure they are of identical size. Incorrect sizes will cause an improper and unsatisfactory bond and may damage the machine.

23-68. Always select swaging rolls and guide sockets to fit the work to be done. Cable size are stamped on each one. Rolls for shank type terminals have one cutaway segment, while rolls for ball type work have four. The roll with the two extended pins on its face is the lower roll; and plain one is the upper roll. The rolls must be installed with the lettered face showing.

23-69. **Testing Fabricated Cables.** All locally fabricated, reworked, and repaired cable assemblies must be tested for proper strength before installation. The desired method is to simulate the installation arrangement including pulleys where required (if such simulation is not possible a straight pull test may be made). Apply a test load of 60 percent of the minimum allowable breaking strength gradually to one end of the cable and with the other end securely anchored. Hold the cable under tension for 3 minutes; release and examine it for damage and the fitting for any sign of failure of attachment. Refabricate all cables which do not pass the test.

23-70. A suitable guard should be placed over the cable while it is being tested to prevent injury to personnel or damage to equipment, should the cable break.

24. Aircraft Plumbing Assemblies

24-1. The term "aircraft plumbing" refers not only to the hose, tubing, fittings, and connectors used in the aircraft but also to the processes of forming and installing them.

24-2. Aircraft plumbing lines usually are made of metal tubing and fittings or of flexible hose. Metal tubing and fittings are used in high-pressure or critical systems, while flexible lines are generally used in low-pressure systems for the attachment of units which are subjected to vibration.

24-3. Generally, all copper tubing has been replaced with aluminum alloy or corrosion-resistant steel tubing. The high fatigue factor of copper tubing is the chief reason for its replacement. It becomes hard and brittle from vibration and finally breaks. The workability, resistance to corrosion, and lightweight aluminum alloy are major factors in its adoption for aircraft plumbing.

24-4. In some special high-pressure (3.000 psi) hydraulic installations for the operation of the landing gear, flaps, brakes, and the like, corrosion-resistant steel tubing either annealed or ¼ hard is used. The flared section of steel tubing becomes somewhat stronger from cold-working and strain-hardening during the flaring process; its higher tensil strength permits the use of tubing with thinner walls. The final installation weight is not much greater than that of the thicker walled aluminum alloy tubing.

24-5. **Identification of Materials.** Before makking repairs to any of the aircraft plumbing, it is of the utmost importance that you make accurate identification of the plumbing materials. This can be done easily by sight when a synthetic rubber, aluminum alloy, or steel is used as the basic plumbing material. However, it is quite difficult to determine whether a material is 1100, 3003, 5052-0, or 2024T aluminum alloy material.

24-6. You may have to analyze a system as to the pressures involved and the fluid contained. Test samples of the material for hardness by filing or scratching with a scriber, or compare code markings of the replacement parts with the original installation. Always refer to technical orders for information and to check the accuracy of your findings.

24-7. The actual alloy designation is stamped on the surface of the large aluminum alloy tubing. On small aluminum alloy tubing, the designation may be stamped on the surface, but more often it is shown by a color code. Bands of the color code, not more than 4 inches in width, are painted at the two ends and approximately midway between the ends of the tubing. When the band consists of two colors, one-half of the width of the color band is used for each color.

24-8. The painted color codes used to identify aluminum alloy tubing are given in table 3. For example, 2014 aluminum alloy is gray and 6053 aluminum alloy is black.

24-9. Aluminum alloy tubing, 1100 (½ hard) or 3003 (½ hard), is used for general purpose lines of low or negligible fluid pressures, such as instrument lines and ventiliating conduits. The 2024T and 5052-0 aluminum alloy materials are used in general purpose systems of low and medium pressures, such as hydraulic and pneumatic 1000 to 1500 psi systems and fuel and oil lines. Occasionally, these materials are used in high pressure (3,000 psi) systems.

24-10. Tubing made either from 2024T and 5052-0 material will stand a fairly high pressure before bursting. These materials are easily flared and are soft enough to be formed with handtools. Be very careful when working or handling tubing to prevent dents, scratches, and nicks.

24-11. Corrosion-resistant steel tubing, annealed ¼ hard, is used extensively in high-pressure (3,000 psi) hydraulic systems for the operation of the landing gear, flaps, brakes, and the like. External brake lines should always be made of corrosion-resistant steel to minimize damage from flying rocks during takeoff, landing, and from careless ground handling. Steel tubing is identified by code colors painted on its surface.

24-12. Synthetic rubber hose of various types and construction is used in aircraft plumbing in both low- and medium-pressure systems. Hose is especially suitable where a great amount of flexibility is needed and where lines are subject to engine vibration. It may also serve as a connector in metal tubing lines. For drain lines and venting systems, smaller types of hose are used.

24-13. Several types of approved hose are suitable for use in fuel, oil, coolant, and hydraulic systems. Lines, letters, and numbers printed on the hose are used for identification. This coding includes such information as hose size, manufacturer, date of manufacture, and pressure and temperature limits. In some instances, several types of hose may be suitable for the same usage. Therefore, in order to make the correct hose selection, always refer to the appropriate -2 or -3 technical order for the particular aircraft.

TABLE 3

ALUMINUM ALLOY IDENTITY COLOR CODES

Aluminum Alloy	*Color*
1100	White
3003	Green
2014	Gray
2024	Red
5052	Purple
6053	Black
6061	Blue and Yellow
7075	Brown and Yellow

53450-4-4-T1

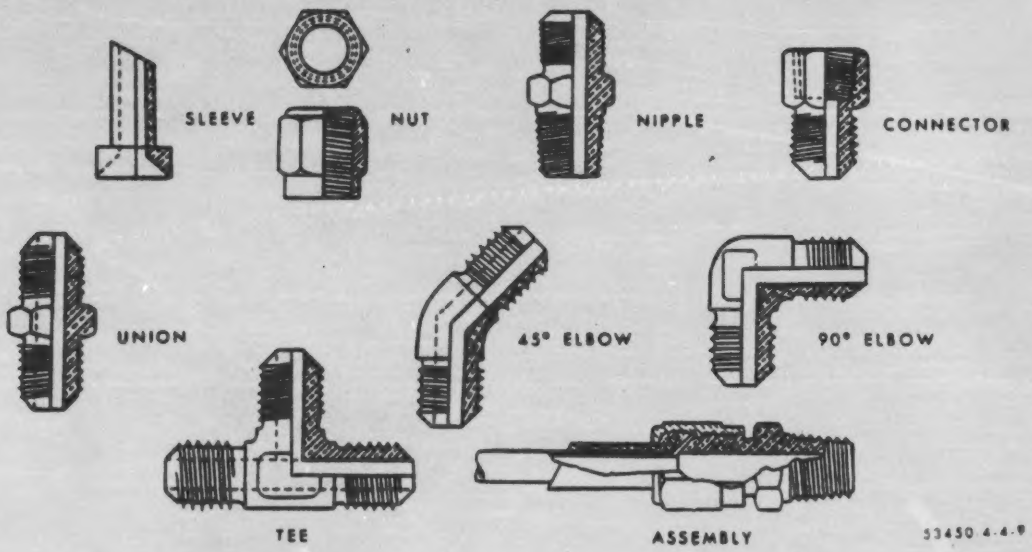


Figure 76. Plumbing fittings.

24-14. *Connectors.* Plumbing connectors are used for attaching one piece of tubing to another or to system units. There are three types of connectors: flared, bead-and-clamp, and swaged. The amount of pressure and plumbing content determines which connector to use. The beaded type of joint, which requires a bead and a section of hose and hose clamps, is used only in low- or medium-pressure systems, such as vacuum and coolant systems. The flared and swaged types may be used as connectors in all systems, no matter what the pressure is. Only the flared and the beaded type connector can be fabricated by the airframe repairman.

24-15. *Flared fitting.* The AN standard fitting is the most commonly used flared tubing assembly for attaching the tubing to the various fittings required in the tubing systems of an aircraft (see fig. 76). The AN standard fittings include the AN818 nut and AN819 sleeve. The AN817 sleeve nut incorporates the functions of both the AN818 nut and AN819 sleeve.

24-16. The AN819 sleeve is used in conjunction with the AN818 coupling nut. All of these fittings have straight threads, but they have different pitch for the various types. AN standard fittings have superseded all other types used by the Air Force, Army, and Navy and should be used in preference to all others.

24-17. Fittings may be of aluminum alloy, steel, or copper base alloys. For identification purposes, all AN steel fittings are colored black, and all AN aluminum alloy fittings are colored blue. The AN819 aluminum bronze sleeves are cadmium plated and are not colored. The size of these fittings is given in dash numbers which equal the nominal tube outside diameter (often indicated by the letters OF) in sixteenths of an inch.

24-18. The three-piece solderless union is one of the most common connectors used for connecting flared tubing. It is generally used in oxygen systems and in high-pressure hydraulic systems, such as landing gear and brake systems. The union consists of a coupling nut, a sleeve, and a body piece. The body piece forms the foundation for the flared end of the tubing, which in turn is held down by the sleeve and coupling nut (hex nut). The body piece may be equipped with a nut having a shoulder under which a sealing gasket and washer may be placed during installation.

24-19. *Flexible connectors.* Flexible connectors may be equipped with either swage fittings or detachable fittings; or they may be used in conjunction with beads and hose clamps. Those equipped with swaged fittings are ordered by correct length from the manufacturer and cannot be assembled by the repairman. They come factory swaged and tested and are equipped with authorized standard fittings.

24-20. *Detachable type connectors.* These fittings can be detached and reused on low- and medium-pressure lines conducting fuel, hydraulic fluid, glycol, water, deicing fluid, and fire-extinguishing fluids.

24-21. The bead and hose clamp connector is often used for connecting oil, coolant, and low-pressure fuel system tubing. The beading of the tubing gives a good gripping edge which aids in holding the clamp and hose in place. The bead may appear near the end of the metal tubing or on one end of a fitting; a pipe thread which will fit snugly into the unit to be connected may be at the other end of the fitting.

24-22. **System Coding.** For identification of the various fluid lines, code bands of colored tape are placed around the tubing near the system units and joints and at intermediate points. This permits easy tracing of the line or system throughout the aircraft. If more information is needed to identify plumbing lines by color code band marking, consult TO 1-1A-8.

24-23. **Damage Evaluation.** Damage such as nicking or scratching of tubing can be minimized by using care. Most damage of this kind occurs from careless handling of tools during maintenance of the aircraft. Any dent less than 20 percent of the tubing diameter is not objectionable unless it is on the heel of the short bend radius. A nick no deeper than 15 percent of the wall thickness of aluminum, aluminum alloy, copper, or steel tubing may be reworked by burnishing with hand tools. Any aluminum, aluminum alloy, copper or steel tubing carrying pressures in excess of 100 psi with nicks in excess of 15 percent of the wall thickness should be rejected. Nicked tubing is weakened due to internal pressure, and such nicks must be burnished out to reduce a possible notch effect. If the nicks are not burnished out, consequent stress concentration under vibration will cause weakening and breaking at the nicked point. Burnishing removes the notches by removal of surrounding material. Burnishing is not allowed in the heel of bends where the material has already been stretched thin during forming. Tubing which is nicked in a bend should be replaced if it is carrying over 100 psi. For tubing carrying pressures of 100 psi or less, a nick no deeper than 20 percent of the wall thickness of aluminum, aluminum alloy, copper, or steel tubing may be reworked by burnishing handtools. Where tubing is used for fluids at atmospheric pressure or less, the bursting strength of the tubing is unimportant, but it must be leak-tight at all times. Dents can be removed from tubing by drawing a bullet through the tubing. The diameter of the bullet must be equal to or slightly less than the inside diameter of the tubing.

24-24. **Repair Procedures.** Aircraft tubing is repaired by replacing the damaged section with a connector, hose, or union fitting, or with a new length of tubing of identical or similar material. The length of the tubing removed depends upon the location and the extent of the damage and upon the convenience for tool manipulation.

24-25. If the damaged portion of a line is near a fitting, a union, or a connection, cut the line beyond the point of damage and remove the damaged part. If the damage is not near a fitting, or if the surrounding area is such as to prohibit removing that portion of the line between the damage and the fitting, then cut the line at points where cutting, burring, and repair operations can be done easily. The use of a keyhole hacksaw is recommended for cutting tubing under such conditions. But be careful to prevent filings from entering the lines.

24-26. *Repair of high-pressure lines.* A minor repair in a high-pressure line is one in which the damaged portion does not exceed the length of a union fitting. To make a minor repair, first cut the damaged tubing away, leaving a gap equivalent to the length of a union. Next, slip the fittings on the tubing, flare the ends, and install the union. Support the rear side of the grip die during the flaring operation to avoid bending the tubing.

24-27. A major repair in a high-pressure line is one in which the damaged portion of tubing cannot be replaced by a union fitting alone but requires at least two unions and one length of tubing for the repair.

24-28. To make a major repair, first cut away the damaged section of tubing. Slip fittings on the two pieces of tubing, flare the ends, and attach unions. Accurately measure the distance between the union faces, make an insert, and assemble.

24-29. *Repair of low-pressure lines.* Beaded tube inserts are used in the repair of low-pressure lines. For this repair, cut the insert about ½ inch shorter than the cutaway section of the damaged line. Bend the ends of the tubing and the insert, and cut two pieces of hose, one to fit across each gap. Each piece of hose should be long enough to extend well beyond the beads on the tubing to allow for hose clamps.

24-30. Slip the pieces of hose, with the hose clamps properly located, well back over the ends of the tubing to permit placing the insert into position. Moistening the tubing or the hose will make it easier to slide the hose into place. After the pieces of hose are positioned midway over each joint, tighten the hose clamps.

24-31. In this type of repair, there should be no strain on the hose and no twists in it. If a beaded repair cannot be made on a fuel or oil line, replace the entire line whenever possible. Check the type of hydraulic oil and determine the proper rubber hose specifications prior to repair.

24-32. Oxygen plumbing requires special attention because of the fire hazards caused by leaks and because of the importance of always keeping sufficient line operating pressure. Always consult TO 1-1A-8 and the -2 series for specific type aircraft when attempting to make repairs on an aircraft oxygen plumbing system.

24-33. Prior to installation of fittings (AN/MS) in the oxygen system, it is recommended that each fitting be visually or airflow checked to insure passages are free from obstructions.

24-34. Leakage at oxygen fittings may sometimes be corrected by tightening; but remember, excessive tightening can weaken or destroy the connections. Always use a torque wrench and follow the tables given in TO 1-1A-8.

24-35. Thread compounds should not be used on flared tubing that is used in oxygen systems. The use of thread compounds should be limited to tapered male pipe threads. TO 1-1A-8 and the -2 series for a specific aircraft *must be carefully followed* at all times when fabricating, installing, and inspecting oxygen system plumbing, as only the high points are covered in a general nature in this CDC.

24-36. Damaged tubing and lines should be replaced with new items whenever possible. Sometimes replacement is impractical and repair is necessary. Scratches and abrasions and minor corrosion on the outside of lines may be considered negligible and can be smoothed out with a burnishing tool or aluminum wool. Limitations as to the amount of damage that can be repaired in this manner are prescribed in applicable technical orders and should be rigidly followed. If a line assembly is to be replaced, the fittings often can be salvaged; then the repairs will involve only tube forming and replacement.

24-37. Tube forming consists of four processes: cutting, bending, flaring, and bending. If the tubing is small and of soft material the assembly can be formed by hand bending during installation. If the tubing is larger than ¼-inch diameter, hand bending is impractical.

24-38. Remove the old assembly, taking care not to further damage or distort it, and use it as a forming template for the new part. The old assembly employed as a template should give you a duplicate as to length, bends, and angles. If you are rerouting a line or if the old assembly is not available, make a template of wire, bending the pattern by hand as required for the new assembly. Then bend the tubing to conform to the wire pattern.

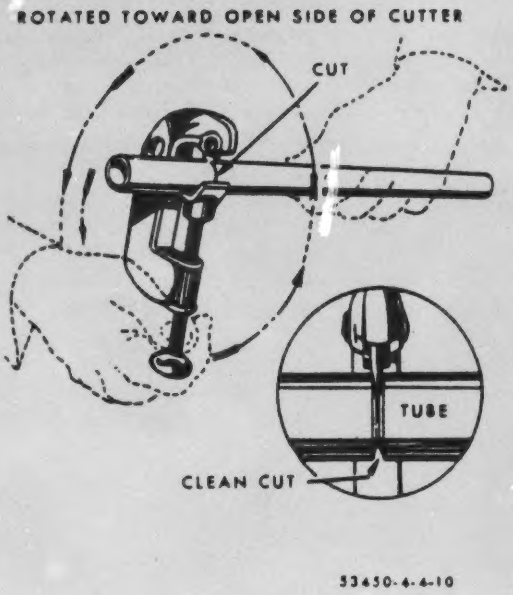


Figure 77. Tube cutter.

24-39. Never select a route which does not require bends. A tube cannot be cut or flared so accurately that it can be installed without bending and still be free from initial mechanical strain. Never make a direct straight-line connection between two fixed attachment points. Bends are necessary to permit the tubing to expand or contract under temperature changes and to absorb vibration. If the tubing is small in diameter (under ¼ inch) and can be hand formed, then add definite bends to avoid a perfectly straight assembly.

24-40. Start all bends at a reasonable distance from the fittings, because the sleeves and nuts must be slipped back during the fabrication of flares and during inspections. In all cases, the new tube assembly should be so formed before installation that it is not necessary to pull the assembly into alignment. Supports, such as clamps and brackets, must be provided at intervals. The requirements for these supports are usually listed in a table of specifications conveniently located in the aircraft.

24-41. *Cutting.* When you are cutting tubing, it is of the utmost importance to produce a square end free of burrs. Tubing may be cut with a tube cutter or a hacksaw. The tube cutter (see fig. 77) is adaptable for use with any soft metal tubing, such as copper, aluminum, or aluminum alloy.

24-42. Place the tubing in the cutting tool with the cutting wheel at the point where the cut is to be made. Rotate the cutter around the tubing, applying a light pressure to the cutting wheel by intermittently twisting the thumbscrew. Too much pressure on the cutting wheel at one time could

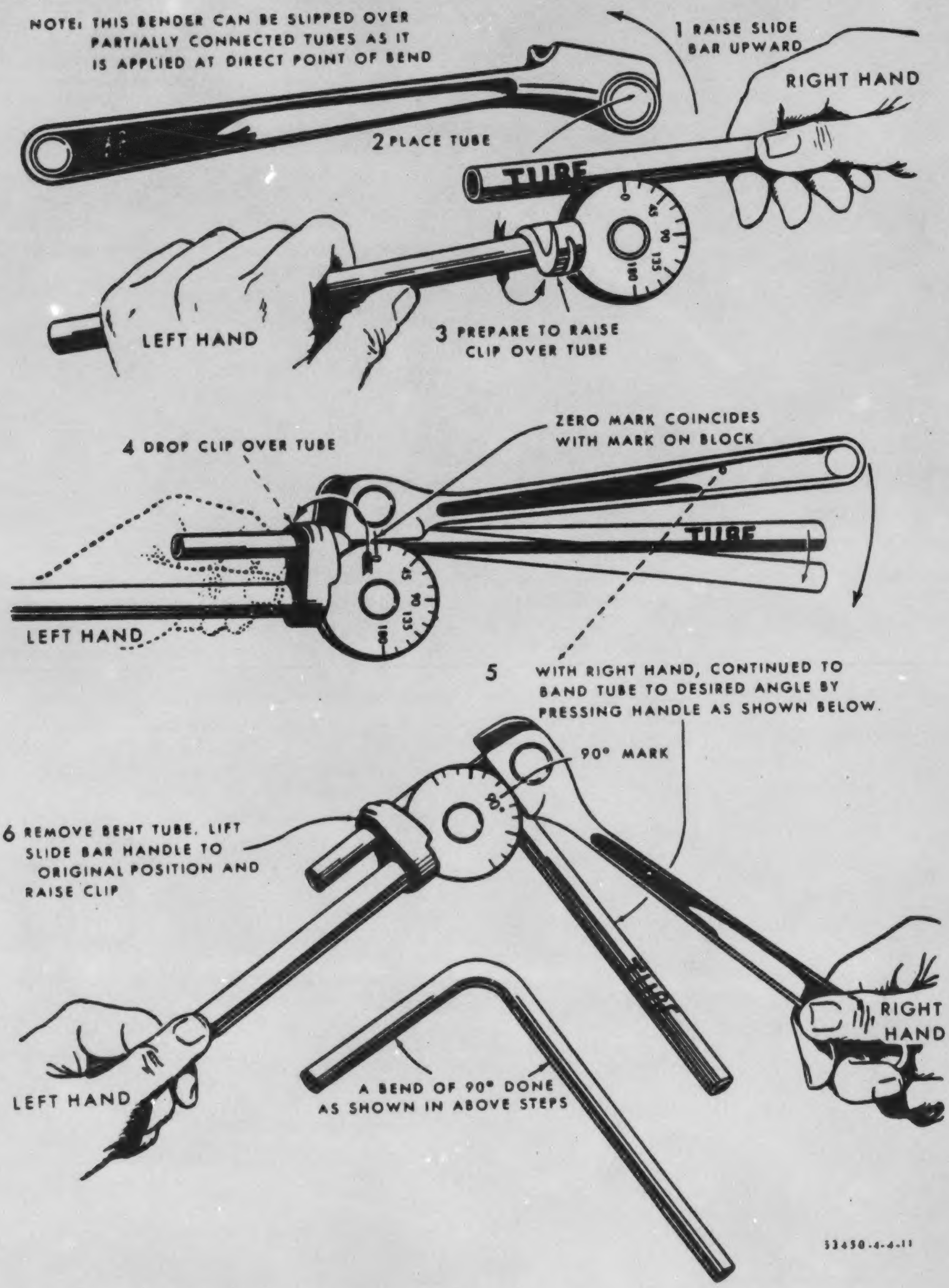

NOTE: THIS BENDER CAN BE SLIPPED OVER PARTIALLY CONNECTED TUBES AS IT IS APPLIED AT DIRECT POINT OF BEND
1 RAISE SLIDE BAR UPWARD
RIGHT HAND
2 PLACE TUBE
TUBE
0
45
90
135
180
LEFT HAND
3 PREPARE TO RAISE CLIP OVER TUBE
ZERO MARK COINCIDES WITH MARK ON BLOCK
4 DROP CLIP OVER TUBE
TUBE
45
90
135
180
LEFT HAND
5 WITH RIGHT HAND, CONTINUED TO BAND TUBE TO DESIRED ANGLE BY PRESSING HANDLE AS SHOWN BELOW.
90° MARK
90
6 REMOVE BENT TUBE. LIFT SLIDE BAR HANDLE TO ORIGINAL POSITION AND RAISE CLIP
TUBE
RIGHT HAND
LEFT HAND
A BEND OF 90° DONE AS SHOWN IN ABOVE STEPS
33450-4-4-11

Figure 78. Hand tube bender.

deform the tubing or cause excessive burring. After cutting the tubing, carefully remove any burrs from the inside and outside of the tube. Use a knife or the burring edge attached to the tube cutter.

24-43. If a tube cutter is not available, or if tubing of hard material is to be cut, use a fine-toothed hacksaw, preferably one having 32 teeth per inch. After sawing, file the end of the tube square and smooth and remove all burrs.

24-44. An easy way to hold small diameter tubing when cutting it is to place the tube in a combination flaring tool and clamp the tool in a vise. Make your cut at a distance of about ½ inch from the flaring tool. This procedure keeps sawing vibrations at a minimum and prevents damage to the tubing which could result if hit with the hacksaw frame or file handle while cutting. Be sure that all filings and cuttings are removed from the tube.

24-45. *Bending*. When bending tubing, try to produce a smooth, even bend without its flattening or buckling. All tubing used in aircraft plumbing should be in the annealed stage before bending; otherwise it may crack.

24-46. Several methods are used in tube bending. Tubing up to ¼-inch diameter may be bent with the hands without flattening or buckling, if care is taken to work the curve gradually. For sizes larger than ¼-inch diameter, the hand tube bender (shown in fig. 78) provides smooth, accurate bends in thin-walled tubing of soft materials.

24-47. The hand tube bender shown is available in four sizes to accommodate tubing ranging from 3/16- to ⅜-inch outside diameter. Sizes are usually stamped on the bender in 1/16-inch stages. Notice that the block of the tube bender is available to accommodate tubing with 7/16-, ½-, ⅝-, and ¾-inch outside diameters.

24-48. To bend tubing with the hand tube bender, place the tubing so that the bend mark is in line with the zero mark on the radius block. Adjust the handle so that the full length of the groove in the slide bar is in contact with the tubing. The bend mark must coincide with both the zero mark on the radius block and the mark on the slide bar. Make the bend by rotating the handle until the desired angle of bend is obtained, as indicated on the radius block.

24-49. Tube bending machines for bending all types of tubing are generally used in depots and maintenance shops. With such equipment, proper bends may be made on tubing of large diameters and hard materials. The production tube bender is an example of this type of machine.

24-50. The ordinary production tube bender will accommodate tubing ranging from ½- to 1½-inch outside diameter. Benders for larger sizes are available, and the principle of their operation is similar to that of the hand tube bender. The radius blocks are so constructed that the radius of bend will vary with the tubing diameter. The radius of bend is usually stamped on the block.

24-51. When hand or production tube benders are not available or are not suitable for a particular bending operation, a filler of metallic composition or of dry sand may be used to facilitate bending. When using this method, cut the tube slightly longer than is required. The extra length is for putting a plug (which may be wooden) in each end.

24-52. After plugging one end, fill and pack the tube with fine, dry sand and plug tightly. Both plugs must be tight so they will not be forced out when the bend is made. The tube may also be closed by flattening the ends or by soldering metal discs in them. After the ends are closed, bend the tubing over a forming block shaped to the radius specified in the technical order.

24-53. A modified version of the filler method may be exercised by the use of a fusible alloy instead of sand. In this method, the tube is filled under hot water with a fusible alloy which melts readily at 160° F. The alloy-filled tubing is then removed from the water, allowed to cool, and bent *slowly* by hand around a forming block or with a tube bender. After the bend is made, the alloy is again melted under hot water and removed.

24-54. When using either filler method, make certain that all particles of the filler are removed so that none will be carried into the system in which the tubing is installed. Store the fusible alloy filler where it will be free from dust or dirt. It may be remelted and reused as often as desired. Never heat this filler in any other than the prescribed method, as the alloy will stick to the inside of the tubing, making them both unusable.

24-55. *Flaring*. Two kinds of flares are generally used in aircraft plumbing systems, the single flare and the double flare. Either kind may be used when using a three-piece solderless union.

24-56. Because every three-piece fitting requires a flare and is used only in critical places, correct tube flaring is important. Flares are frequently subjected to extremely high pressures; therefore, the flare on the tubing must be properly shaped or the connection will leak or fail.

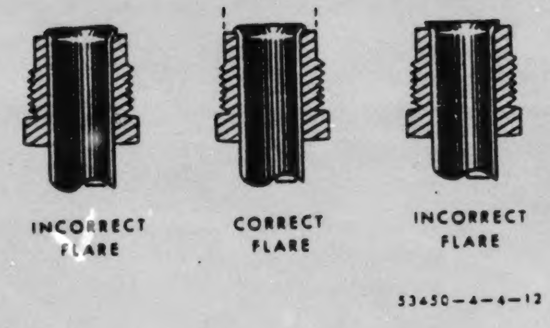


Figure 79. Tube flares.

24-57. A flare made too small produces a weak joint which may leak or pull apart; one made too large interferes with the proper engagement of the screw thread on the fitting and will cause leakage. A crooked flare will result from failure to cut the tubing squarely. If a flare is not properly made, it cannot be corrected by applying additional torque to tighten the fitting. The flare and tubing must be free from cracks, dents, nicks, scratches, or any other defects. (See fig. 79.)

24-58. Most flaring operations are performed with the combination flaring tool (see fig. 80). This tool is designed for use with aluminum alloy tubing and should not be used when you are flaring steel tubing.

24-59. To prepare a tube for flaring, cut it squarely and remove all burrs. Slip the fitting nut and sleeve on the tube and place it in the flaring tool. Center the plunger or flaring pin over the end of the tube. Project the end of the tubing slightly from the top of the flaring tool, about the thickness of a dime, and tighten the clamp bar securely to prevent slippage.

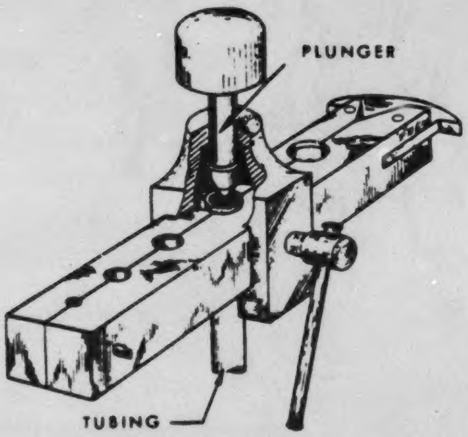


Figure 80. Combination flaring tool.

24-60. Make the flare by striking the plunger several light blows, using a lightweight hammer or mallet. Turn the plunger a half turn after each blow and be sure it seats properly before removing the tube from the flaring tool. Proper seating indicates that the flare is correct. During the flaring operation, hold the tubing and flaring tool in one hand while hammering with the other.

24-61. Both hammer and the ball types of flaring tools are available for use with single-sized tubing. They are especially suitable for soft tubing of moderately heavy wall thickness. The ball type flaring tool is inserted in the tubing up to the tapered portion, and the flare is made by rotating the tool with a moderate downward and outward pressure. After the flare has been formed, the threads in the flaring tool may be engaged with the coupling nut and tightened to properly seat the flare on the sleeve. When the flare is properly seated, unscrew the coupling nut and remove the ball type flaring tool.

24-62. The flaring block or grip die is adaptable for use with heavy-walled tubing, alloy steel tubing, and tubing of other hard material. This tool consists of two steel blocks placed side by side and held in alignment by three steel pilot pins pressed into one block and extending into corresponding holes in the other. A number of countersunk holes are drilled along the length of the block, the holes varying in size to match the various tubing sizes. The angle of flare varies with the size of the tubing.

24-63. The double flaring tool is used for making a double flare, which is used in oxygen systems in conjunction with the three-piece union. The double flare is smoother and more concentric than the single flare and, therefore, makes a better seal. It is also more resistant to the shearing effect of torque (see fig. 81).

24-64. To make the double flare, separate the clamp blocks of the double flaring tool and insert and clamp the tubing with the burred end flush with the top of the clamp. Insert the starting pin in the flaring pin guide and with a hammer strike the pin sharply until the shoulder of the pin stops against the clamp blocks. Remove the starting pin and insert the finishing pin, and hammer it until its shoulder rests on the clamp block.

24-65. Since the oxygen system is a highly critical system, only a symmetrically formed double flare should be considered acceptable.

24-66. *Beading*. Tubing may be beaded with a hand beading tool, with machine beading rolls, or with grip dies. The method to be used de-

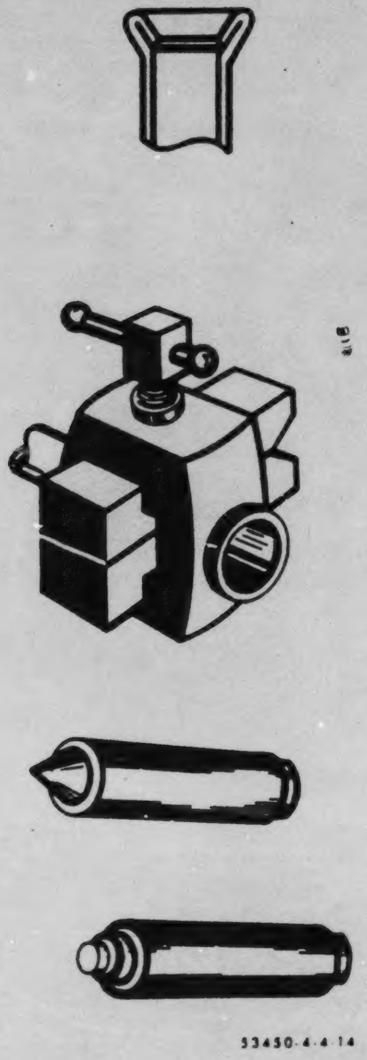


Figure 81. Double flaring tool.

pends on the tubes's diameter and wall thickness and on the material from which it was made.

24-67. The hand beading tool is used with tubing having ¼- to 1-inch outside diameter. The bead is formed by using the beader frame with the correct rollers attached. The inside and outside of the tube is lubricated with light oil to reduce the friction between the rollers during beading. The sizes marked in sixteenths of an inch on the rollers are for the outside diameter of the tubing which can be beaded with that size roller.

24-68. Separate rollers are required for the inside of each tubing size, and care must be taken to use the correct parts when beading. The hand beading tool works somewhat like the tube cutter in that the roller is screwed down progressively. In addition, a small vise (tube holder) is furnished with the kit.

24-69. Other methods and types of beading tools and machines are available, but the hand beading tool is the most used. As a rule, beading machines are limited to usage with large diameter tubing over $1\frac{15}{16}$ inch unless special rollers are supplied. The grip die method of beading is confined to small tubing.

24-70. **Installation Techniques.** Before installing a line assembly in an aircraft, inspect the line carefully. Remove dents, scratches, and the like, and be sure all nuts and sleeves are snugly mated and securely fitted by proper flaring of the tubing. The line assembly should be clean and free from all foreign matter.

24-71. Never apply compound to the faces of the nipple or the flare, for it will destroy the metal-to-metal contact between the tubing and flare which is necessary to produce the seal. Be sure that the line assembly is properly aligned before tightening the fittings; do not pull the installation into place with torque on the nut. On synthetic hose lines or connections, the colored stripe which extends the length of the flexible hose should be straight (that is, it should not be twisted when installed).

24-72. *Plumbing assembly precautions.* As a matter of precaution, be sure that the material in the fittings you use is similar to that of the tubing; for example, use steel fittings with steel tubing and aluminum alloy fittings with aluminum alloy tubing. Brass fittings, plated with cadmium, are sometimes used with aluminum alloy tubing.

24-73. For corrosion prevention, aluminum alloy lines and fittings must be anodized. Steel lines and fittings, if not stainless steel, must be plated to prevent rusting or corroding. Brass and steel fittings are usually cadmium plated, although some may come plated with nickel, chromium, or tin.

24-74. *Torquing.* You should tighten fitting nuts to the correct torque value when installing a tube assembly. *Never* use pliers or adjustable wrenches to tighten fittings. Either a cutaway box-end or an open-end wrench is best for tightening fittings.

24-75. If a torque-indicating wrench is available, torque the fitting nuts to their final tightness. Always use wrenches in pairs, one to hold the fitting and the other to tighten the nut.

24-76. To overtighten a fitting may badly damage or completely cut off the tube flare, or it may ruin the sleeve or the fitting nut. Failure to tighten sufficiently can be equally serious, as this condition may allow the lines to blow out of the assembly or to leak under system pressure. The use of torque wrenches and the prescribed torquing values prevent overtightening or undertightening.

24-77. A fitting nut should never be tightened when there is pressure in the line. The pressure could damage the flare and also cause an incorrect torque to be applied. If a tube fitting assembly is tightened properly, it may be removed and retorqued many times before reflaring is necessary. Always refer to torquing tables for correct torquing limits; they will vary with the material used, with tubing and nut size, and with the type of fitting. Be extremely careful when tightening fittings with thread compound on them. The compound makes it difficult to feel how tight you are getting the fittings.

24-78. To insure proper sealing of hose connections and to prevent breaking hose clamps or damaging the hose, follow the hose tightening instructions carefully. When available, use the hose clamp torque limiting wrench. This wrench is available in 15 and 25 pound-inch calibrations. If there are no torque-limiting wrenches available, use the fingertight plus limits as given in TO 1-1A-8.

24-79. Because of the variations in hose clamp design and structure, the values given in the technical order torque table are approximate. Therefore, use judgment when tightening hose clamps by this method. Since hose connectors are subject to "cold flow" or a setting process, a followup tightening check should be made for several days after installation or until you think that the hose has finished the cold flowing or setting process.

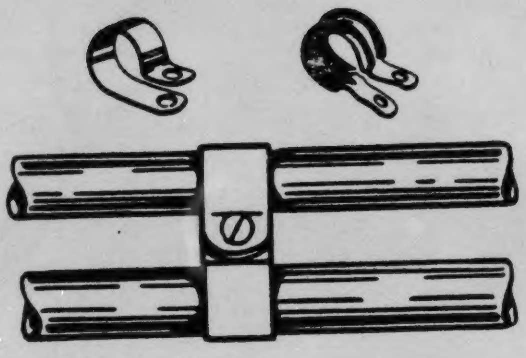


Figure 82. Bonding clamps for tubing.

24-80. *Use of support clamps.* Support clamps are used to secure the various lines to the airframe or to the strut assembly. There are two types of support clamps generally used for this purpose: rubber-cushioned and plain. The rubber-cushioned clamp is used to secure lines which are subject to vibration; the cushioning prevents chafing of the tubing. The plain clamp is used to secure lines in areas not subject to vibration (see fig. 82).

24-81. All lines that extend over a long distance, whether a single line or two or more lines following parallel courses, must be secured at specified intervals. The table for maximum distance between supports for fluid tubing may be found in TO 1-1A-8.

24-82. **Inspection of Completed Repairs.** Inspection of completed repairs include such items as checking for proper fits, rubbing, leaks, and correct color coding of installed lines. As mentioned before, careful consideration should be given to oxygen lines and leaks which cannot be stopped by simply tightening the fitting some more. When specified torques are exceeded it will only result in a damaged or destroyed fitting. In most cases it is better to remove the tubing if it leaks, check for burrs, scars, cracks, presence of foreign matter and improper fits. The final check is to make certain the newly installed line is correctly color coded for future identification. You may consult TO 1-1A-8 for color code charts.

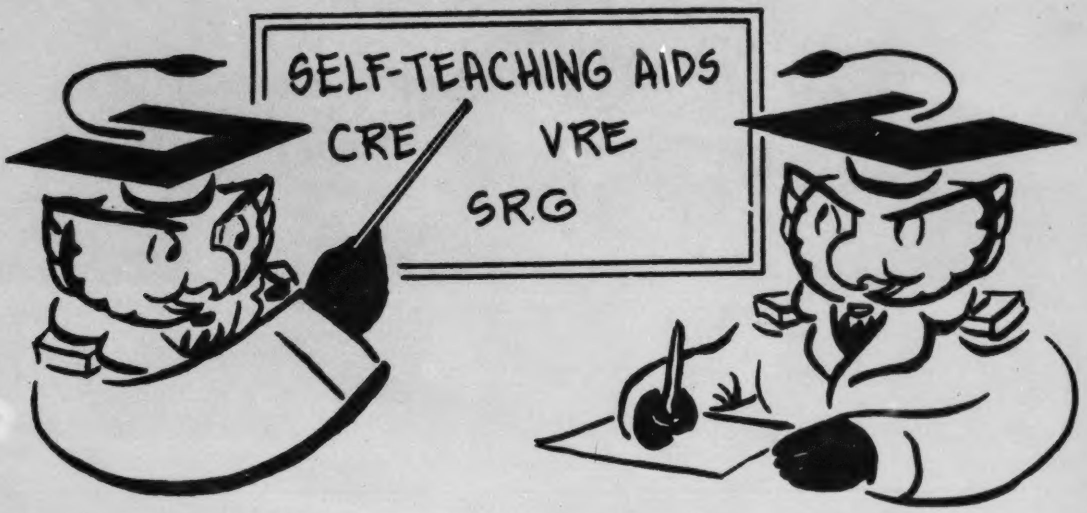
508

2-3

53450 04 24

WORKBOOK

Specialized Repairs



This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

EXTENSION COURSE INSTITUTE

Air University

517

TABLE OF CONTENTS

Study Reference Guide

Chapter Review Exercises

Answers to Chapter Review Exercises

Volume Review Exercise

ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate these numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number	*Guide Numbers 400 through 427*
400	Introduction to Transparent Enclosures; Transparent Plastics; Classes and Types; Identification. pages 1-3
401	Storage; Cleaning. pages 3-5
402	Inspection. pages 5-7
403	Maintenance of Acrylic Plastics: General; Machining; Cutting; Drilling; Smoothing and Routing. pages 7-10
404	Maintenance of Acrylic Plastics: Forming; Sanding; Ashing; Finishing. pages 10-13
405	Maintenance of Acrylic Plastics: Cementing; Annealing. pages 13-16
406	Laminated Plastics; Cellulose Acetate Base Plastics; Hot Climate Precautions; Painting Precautions. pages 16-19
407	Installation. pages 19-23
408	Introduction to Fiberglass Enclosures and Parts; Mat Molded. pages 24-28
409	Laminates: General; Construction Features. pages 28-34
410	Laminates: Damage Evaluation; Materials, Tools, and Equipment. pages 34-36
411	Laminates: Repair Methods. pages 36-40
412	Laminates: Quality Inspection. pages 40-42
413	Honeycomb Core: Construction Features; Damage Evaluation; Materials, Tools, and Equipment. pages 42-45
414	Honeycomb Core: Repair Methods; Quality Inspection; Safety Precautions. pages 45-49
415	Fluted Core. pages 49-51
416	Foam Core; Removal and Replacement of Enclosure. pages 51-54
Guide Number	
417	Introduction to Metal Bonded Honeycomb; Honeycomb Assemblies; Honeycomb Damage. pages 55-59
418	Honeycomb Repair: Tools and Equipment; Fire Precautions; Handtools and Equipment. pages 59-63
419	Honeycomb Repair: Repair Materials. pages 63-65
420	Honeycomb Repair: Potted Compound Repair; Skin Delamination and Crack Repairs. pages 65-67
421	Honeycomb Repair: Repair of Transition Area; Tapered Trailing Edge Repair. pages 67-71
422	Honeycomb Repair: Bonded Honeycomb Skin and Core Repair; Inspection of Completed Repair. pages 71-73
423	Introduction to Aircraft Cable and Plumbing Repair; Aircraft Cables: General; Cable Construction; Damage Evaluations. pages 74-76
424	Aircraft Cables: Hardware; Tensiometer. pages 76-79
425	Aircraft Cables: Fabrication; Kearney Swaging Machine; Testing Fabricated Cables. pages 79-82
426	Aircraft Plumbing Assemblies: General; Identification of Materials; System Coding; Damage Evaluation. pages 82-85
427	Aircraft Plumbing Assemblies: Repair Procedures; Installation Techniques; Inspection of Completed Repairs. pages 85-91

CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Section 1

Objective: To give some of the historical facts about the development of plastics.

1. The plastic industry began in 1870 with a new material called celluloid. (True or False.) (1-1)

Section 2

Objectives: To list various types of plastics, explain how they are formed and how they are used on aircraft.

1. What are the classes and types of transparent plastic used on aircraft? (2-4–9)

2. In forming or fabricating plastic materials, how are thermoplastic and thermosetting materials similar? (2-6)

3. Once formed, how do physical properties of thermoplastic and thermosetting plastic products differ? (2-6, 7)

4. Why are acrylic plastics so popular in use on aircraft? (2-8, 9)

Section 3

Objectives: To identify plastics and explain the difference between plate glass and transparent plastic enclosures.

1. How are plastics identified for selection and requisition? (3-5)

2. How can you distinguish the difference between a plate glass enclosure and a transparent plastic enclosure? (3-6)

3. How can you tell if certain samples of plastic materials are of the acrylic plastic? (3-7–10)

Section 4

Objective: To list the safety precautions as related to the storage of plastics.

1. What precautions should you take in storing plastic sheets of various sizes? (4-1, 5, 6)

2. Why is storage of acrylic plastics prior to use so important? (4-7)

Section 5

Objective: To give the correct methods for cleaning transparent enclosures.

1. What are the procedures for cleaning transparent plastics? (5-1)

2. Why is the surface of plastic enclosures flush with water before applying an approved cleaner? (5-1b, 3)

Section 6

Objective: To inspect for possible damage, defects, and possible leaks in transparent plastic assemblies.

1. When inspecting plastics, what is the most common defect to be found and why are some not acceptable? (6-2, 13)

2. Explain how to check for air leakage between dual plastic panels? (6-6)

3. Describe procedures for identifying glass delamination. (6-6)

4. How would you identify a chip in an aircraft window glass? (6-7)

Section 7

Objective: To demonstrate a knowledge of the various methods used in the maintenance of acrylic plastics.

1. What is used to prevent burning and clogging of a drill or saw when they are used to machine plastics? (7-2)

2. What equipment is used to cut plastic sheets? (7-5)

3. The use of hot water or direct steam to heat transparent plastics may cause it to ____. (7-21)

4. How should the original luster and transparency of transparent plastics always be protected? (7-32)

5. If the highly polished finish on acrylic plastic domes, sighting panel, or other critical optical parts are scratched, how will they be treated? (7-39)

6. What should be done to the surfaces of plastic materials prior to applying cement? (7-61)

7. To prevent crazing during bonding and cementing transparent plastic, it must be ______. (7-62)

8. How are plastics annealed? (7-68)

Section 8

Objective: To explain how laminated sheets are formed.

1. What methods can you use to form a laminate plastic sheet? (8-6, 7)

Section 9

Objective: To give the type of cement used in cellulose acetate base plastics.

1. What cement is best to use for joining cellulose acetate base plastic where transparency must be maintained? (9-2-4)

Section 10

Objective: To learn how to correctly remove canopy covers from an aircraft.

1. How are canopy covers removed from an aircraft? (10-3)

Section 11

Objective: To give the safety precautions to follow when painting around canopies.

1. How are canopies protected when paint stripping compounds and organic solvents are used for cleaning an aircraft? (11-1-3)

Section 12

Objective: To explain how to safely install transparent plastic enclosures.

1. Explain the requirements for fitting of transparent plastics into retaining frames. (12-2, 3)

2. Why is it important to install panels correctly? (12-2. 3. 23)

3. Explain the effects of improper torque applied to bolts and screws in installation of glass and plastic panels. (12-2. 3. 23)

4. If a plastic enclosure does not fit loosely in the retaining frame, what would you do? (12-2. 23)

5. Explain methods for insuring use of correct hardware in installing transparent panels. (12-3. 4. 23)

6. Describe general procedures for removing and applying sealants and aerodynamic smoothers to transparent enclosures. (12-7; 9-16)

CHAPTER 2

Section 13

Objectives: To learn the construction features, types of damages, materials, tools and equipment, repair methods, inspection, and safety precautions of fiberglass enclosures.

1. Explain how to identify mat molded fiberglass. (13-3, 8, 25)

2. Identify various parting films and describe their working characteristics for a mat molded repair. (13-6, 7)

3. Explain reasons for each step in the apportioning and mixing of mat molded repair materials. (13-9–13)

4. Identify improper and dangerous actions and explain the correct procedures in handling and mixing resins, catalysts, and promoters for mat molded repairs. (13-9–11, 13, 26)

5. Describe the characteristics of polyester resins and explain the functions of catalysts and promoters in resin mixtures for a mat molded repair. (13-9–11)

6. Explain the correct procedures for mixing resin and catalyst and the hazards involved. Describe what happens when safety precautions are not followed. (13-9–13, 26)

Section 14

Objectives: To identify reinforcement materials used for laminates; to explain the repair methods and the proper tools to be used in laminate construction.

1. Identify fiberglass cloth using CRE figure 1. and describe its structural property. (14-2–4; Fig. 8)

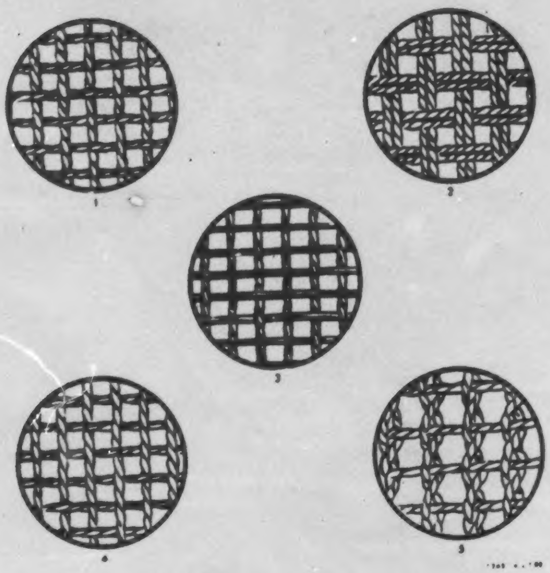


Figure CRE 1. Weaver patterns for fiberglass cloth.

2. Upon inspection of an aircraft radome, you found a soft spot approximately 2 inches in diameter and 12 inches from the edges. Using Chart 1. classify the damage. Is it reparable, and where can the repair procedures be found? (14-10. 23. 24; Chart 1)

3. Explain methods for a minor repair of laminated fiberglass. (14-10, 19; Chart 1)

4. Describe fabrication and application of a vacuum bag for pressure curing repairs to laminated fiberglass. (14-14)

5. You have just finished a repair to a fiberglass laminate part. To cure the repair, you placed a heating lamp over the repair. The lamp was centered 30 inches over the repair to attain a temperature of 130°. The length for curing was 1 hour. After 1 hour the repair surface was still soft. Why didn't the repair cure in the length of time given? (14-15)

6. Outline damage area on a fiberglass laminate radome to the shape of a square. Round all corners. Count the damaged plies. When three plies are damaged, subtract one ply and multiply by 1 inch. This leaves 2 inches to be measured from outline of damage. Use a sharp knife, cut outer line, and remove the top ply. Do not cut into the next ply as it will weaken the repair. Outline exposed ply as you did the first (minus 1 inch). Remove the ply. Clean area by lightly sanding it. Cut replacement plies from glass cloth. Saturate with resin mix. Place the innermost ply in the repair area, being sure to place the direction of weave in the same direction as the existing plies. Place PVA film over patch and sweep out all bubbles and excess resin. Cure the patch. After it has cured, repeat the process for the other ply. After the repair cured, you noticed many little threads in a random pattern and a separation of a ply. Determine the cause of ply separation and the little threads in the cured repair. (14-20–22)

7. Explain the need for surface finishing of laminated fiberglass. (14-22, 24)

8. Explain quality requirements for laminated fiberglass repairs and explain repair inspection methods. (14-24, 25)

Section 15

Objectives: To learn the construction features of the honeycomb core; to demonstrate an ability to use proper tools and equipment for various repair methods.

1. Explain why and when a repair involving damage to the core of honeycomb fiberglass is necessary and why each step in the repair is needed. (15-1–3, 16, 17, 24)

2. Describe construction features and dielectric characteristics of honeycomb core fiberglass. (15-2–4)

3. Explain inspection and testing methods for determining defects in honeycomb core fiberglass. (15-7, 9)

4. Explain the reason for each step in the use of a moisture register during inspection of honeycomb fiberglass radomes. (15-9)

5. A damage is found on a radome at station 92 and 5 inches below the waterline. There is a 2-inch diameter hole through the facing and into the core material. Who will make the repair and why? (15-14; 14-11, 27; Figs. 29, 30)

6. Explain why each step is needed in repairs of outer coating and first ply of honeycomb core fiberglass skin. (15-24; 14-18, 21)

7. Explain why each step is needed in repair of small punctures in the skin of honeycomb core. (15-24, 27)

8. Explain how to use a hardness tester in the inspection of honeycomb core fiberglass. (15-39; 14-25, 26)

Section 16

Objectives: To demonstrate a knowledge of the construction of a fluted core and how to make damage evaluations.

1. Describe structural properties of fluted core fiberglass enclosures. (16-1)

2. Explain why each step is needed in the removal of damaged flutes in fluted core fiberglass enclosures. (16-3; 14-16, 20)

3. Explain why and when installation of replacement flutes in fluted core fiberglass enclosures is necessary and why each step in the installation is needed. (16-3, 5, 6)

4. Explain similarities in repairs of fluted core and honeycomb core fiberglass. (16-5, 6)

Section 17

Objectives: To show a knowledge of foam core construction, repair methods used, and the application of proper tools and equipment.

1. Explain why and when core structure of foam core fiberglass should be repaired and why each step is needed in the repairs. (17-1, 2, 7)

2. Describe construction features of foam core fiberglass radomes. (17-2)

3. Explain the similarities in repairs and inspections of foam core and honeycomb core fiberglass radomes. (17-6, 7, 10)

4. Describe general procedures for mixing plastic foam materials. (17-6, 8, 14)

Section 18

Objective: To show a knowledge of the removal and replacement of enclosures.

1. Explain precautions in handling fiberglass enclosures. (18-1, 2)

2. An airman was directed to get a fiberglass enclosure from an aircraft and take it to the repair shop for repairs. He ordered a pickup truck. With the help of another airman, he loaded the enclosure into the truckbed, setting it on the outer facing. He blocked it so it would not move or slide. Did the airman use correct procedures for transporting the enclosure? If he didn't, what should he have done? (18-1, 2)

3. Explain why each step is needed in the repair of predrilled attachment holes for installation of fiberglass enclosure frames. (18-2; 14-20)

4. Explain requirements for sanding or shaving fiberglass enclosure edge bands. (18-3)

5. Describe requirements for sealing and aerodynamic smoothing of fiberglass enclosure hardware. (18-4, 5, 6)

CHAPTER 3

Section 19

Objective: To demonstrate an ability to identify and point out the characteristics of sandwich (metal bonded honeycomb) construction.

1. What is the most logical reason for an aircraft designer selecting metal bonded honeycomb assemblies for installation in any specified area? (19-2)

Section 20

Objective: To show an ability to describe and locate by various inspection methods damage in metal bonded honeycomb assemblies.

1. Describe the damage that sonic vibration might cause to metal bonded honeycomb panels. (20-2)

2. Why must the inspection of metal bonded honeycomb panels be more critical than that for conventional structures? (20-2)

3. Beside thumb pressure and visual checks, what are three other methods used to test metal bonded honeycomb panels for delaminations? (20-4, 6, 12)

4. What solution is used to locate scratches on aluminum surface panels? (20-8)

5. An inspection of the metal bonded honeycomb panels on a B-52G aircraft reveals minor delaminations. Where will you find the information needed to determine the next step? (20-17)

Section 21

Objectives: To demonstrate an ability to name the tools and equipment, repair materials, and explain their proper use in the safe repair of metal bonded honeycomb assemblies.

1. What tool is used to remove damaged material from metal bonded honeycomb panels? (21-3)

2. A panel has core damage extending 0.500 inch beneath the surface of the panel. Starting at zero, approximately how many turns of the router support assembly must you make to cut out the damaged area? (21-3)

3. What devices could be used to insure the removal of the exact required diameter of material from a 2-inch damaged area? (21-3)

4. How may you insure that only a minimum amount of material is to be removed during the routing operation? (21-6)

5. When aluminum core cells are damaged during routing, what corrective action should be taken? (21-6)

6. Why are pressure jigs used? (21-7)

7. How are the correct proportions of epoxies, resins, and microballoons measured? (21-10)

8. If you had to speed up the drying or curing time of the adhesives of a metal bonded honeycomb repair, how would you do it? (21-11)

9. What is the purpose of an explosive meter? When would it be used in a metal bonded honeycomb repair? (21-14)

10. The honeycomb structural repair kit contains the necessary tools, _____, and _____ required to make the metal bonded honeycomb repairs. (21-16)

11. Why is it particularly necessary to observe all fire precautions when making metal bonded honeycomb repairs? (21-17)

12. What cleaning solvent is usually effective in cleaning a surface to prepare it for glass fabric cloth overlay repairs? (21-21)

13. What is a water break test? (21-24)

14. Why are primers used when making metal bonded honeycomb repairs? (21-25)

15. What ingredients and in what proportions are these ingredients used in the adhesive mixture for glass fabric cloth overlay repairs? (21-27)

16. What ingredients are used in the mixture for a potted compound repair? (21-28)

17. A metal bonded honeycomb panel has damaged aluminum core materials. What type of core material would be used as a repair material? Why? (21-29)

18. How many layers of glass fabric cloth number 181 are required in the repair of the flat surface of a metal bonded honeycomb panel? (21-30)

19. A transition area requires repair by the use of the glass fabric cloth overlay method. How many layers of glass fabric number 181 cloth are recommended for the repair? (21-30)

20. What materials are recommended for use as erosion and corrosion preventives? (21-32)

21. What is the purpose of the pieces of sheet plastic used in the repair procedures when making a potted compound repair? (21-39)

22. Removal of the Duxseal dam and the top piece of sheet plastic from a potted compound repair often leaves a slight protruding stem of material. How is this stem of material removed? (21-44)

23. A cured potted compound repair must be tested to determine if the repair is satisfactory. How is this test performed and what determines if the repair is satisfactory? (21-45)

24. A metal bonded honeycomb panel on a B–52G aircraft has damage that requires the removal of an area 2 inches in diameter. What type of repair would be made to that area? Why? (21-50)

25. The cutout of damaged material on a honeycomb panel results in a hole in the skin 3⅛ inches in diameter. What will be the diameter of the glass fabric cloth overlay patches when ready for application? (21-52)

26. What is the purpose of a bridge? (21-55)

27. Why is glass fabric cloth number 181 preferred for the overlay method of repair in a transition area repair? (21-56)

28. Prior to making repairs to a damaged trailing edge of a honeycomb panel or section, what publication should be consulted? (21-59)

29. What is meant by buttering a replacement honeycomb core? (21-63)

30. Why is it important for the repair area for a glass fabric cloth overlay repair to be thoroughly cleaned? (21-68)

31. There are three types of repairs that are acceptable and may be applied in the damages occurring to the honeycomb skin and core materials on the B–52 aircraft. True or False. (21-70)

32. Why are the techniques for removal of damaged honeycomb skin and core material for one glass fabric cloth overlay repair not applicable for all glass fabric cloth overlay repairs? (21-73)

33. After the core plug has been properly installed into the repair area, what should be done? (21-75)

34. Why should the core plug repair be cured for a period of at least ½ to 1 hour? (21-75)

Section 22

Objective: To show an ability to give the principal factor that must be considered when making or inspecting completed repairs.

1. What are the most important factors to consider when inspecting a completed repair? (22-1)

CHAPTER 4

Section 23

Objective: To demonstrate a knowledge of the repair of control cable assemblies, using the data given on construction features, damage evaluation, repair material, and fabrication and inspection of completed repairs.

1. In similar installations, one with a push rod and one with cables, which would be more apt to break? (23-3)

2. Why is regular lay most commonly used in cable construction? (23-5, 6)

3. Name three reasons for preforming cable strands. (23-7)

4. What is meant by a 7 x 7 (1 WRC) cable? (23-10)

5. What determines the number of broken wires that are allowable in a cable? (23-12)

6. Where must the cable be corroded to make replacement necessary? (23-13)

7. Cable fittings consist of ball type, clevis, turnbuckles, etc. Which fitting serves as a stop? (23-18)

8. Which fitting is used to fasten a cable to an actuator? (23-21)

9. Which fitting is used to adjust tension of the cable? (23-29)

10. What type of cable accessory is used to reduce vibration in a long length of cable? (23-34)

11. When would a tensiometer be used? (23-42)

12. Of the many methods of cutting cable, which should you *not* use? (23-45)

13. What factor must be considered when swaging terminals to cables to assure proper length of the finished cable? (23-49)

14. What check should be made before swaging the terminal to the opposite end of the cable? (23-53)

15. What precaution must be observed in the selection of fluxes in sweat-soldering terminals? (23-56)

16. What is the first step in fabricating a wrap-soldered splice? (23-61)

17. When is it permissible to use a woven-spliced terminal? (23-64)

18. What checks should be made when using the Kearney swaging machine? (23-67)

19. All locally fabricated, reworked, and replaced cable assemblies should be ______. (23-69)

20. What safety precautions should be taken when testing cables? (23-70)

Section 24

Objective: To explain repairs of aircraft plumbing, using given information on the identification of materials, damage evaluation, fabrication, code marking, installation, and final inspection of plumbing repairs.

1. Which material should be used on external brake lines? (24-11)

2. Name the three types of plumbing connectors. (24-14)

3. AN fittings which are blue in color are made of what material? Of what material are black AN fittings made? (24-17)

4. Explain how the different aircraft plumbing systems are identified. (24-22)

5. Damage longer than the length of a union requires what type of a repair in high-pressure lines? (24-27)

6. A beaded type fitting may be used on what type pressure system? (24-29)

7. Why should special attention be given to oxygen systems? (24-32)

8. Why must a section of tubing always contain a bend? (24-39)

9. What tools should be used for cutting tubing? (24-43)

10. What size tubing may be bent by only using your hands? (24-46)

11. What type union must be used with the single flare and double flare. (24-55)

12. Since the oxygen system is a highly critical system, only a symmetrically formed double flare should be considered acceptable. (True or false) (24-65)

13. What kind of wrenches should be used to tighten plumbing fittings? (24-74, 75)

14. What items are checked after the plumbing repairs have been completed? (24-82)

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

Section 1

1. True. (1-1)

Section 2

1. There are two classes of transparent plastics: thermoplastic and thermosetting. The types used are cellulose, acrylic, and laminated. (2-4–9)
2. Thermoplastic and thermosetting material require heat and pressure for forming. (2-6)
3. After forming, thermoplastics can be reheated and reformed, because no chemical change takes place. Thermosetting plastics cannot be reformed as a chemical change takes place and the materials set. (2-6, 7)
4. Acrylic plastics are popular in aircraft because of their high transparent properties, strength-to-weight ratio, and forming ability. (2-8, 9)

Section 3

1. Plastics are identified and requisitioned by a MIL specification number and type of material. (3-5)
2. Transparent plastic enclosures and plastic glass enclosures can be distinguished from each other by lightly tapping the material with a small blunt instrument. Plastic resounds with a dull or soft sound. (3-6)
3. Acrylic plastic can be identified by any of the following methods: burning a small sample for examination of type of flame and odor, viewing from the edge for color, applying zinc chloride or acetone for resulting action, and tapping with a small blunt instrument. (3-7–10)

Section 4

1. Keep masking paper on sheets, stack sheets no higher than 18 inches, the smaller sheets stacked on larger ones. Place in bins tilted at approximately a 10° angle. Store in original containers. Store in cool, dry place, away from solvents and paints. (4-1, 5, 6)
2. When acrylic plastic sheets are improperly stored they become bowed (warped). (4-7)

Section 5

1. Remove jewelry from hands and rinse surface with water using the bare hands to feel for and dislodge dirt, sand, or mud. Wash with mild soap and water. A soft cloth, sponge, or chamois is used in washing but only to carry the soapy water to the plastic. Dry with a damp clean chamois or soft cloth. Do not use a dry cloth, cheesecloth, or unapproved cleaners. (5-1)
2. The surface is always flushed with water before applying an approved cleaner to remove all dirt, sand, grit, or mud. (5-1b, 3)

Section 6

1. The most common defect is scratches. Some are not acceptable when the panel thickness is reduced to less than prescribed by the technical order after the scratch has been worked out. (6-2, 13)
2. Visual check for slight distortion along the edges of the plastic panels, and view it from all angles. Look for a milky (cloudy) appearance around edges of inner or outer plastic panels. (6-6)
3. Glass delamination is identified by viewing the glass and its edges from all angles for any slight distortion. Look for a milky appearance anywhere around the edges of either outer or inner glass or bubbles between the plies. (6-6)
4. The chipped area has a rough or grained appearance which is readily detectable in reflected light. Visibility is poor and distorted. White powdered glass is often seen in the area. (6-7)

Section 7

1. Water and a mild soap solution are used on a drill or saw to prevent burning and clogging when they are used to machine plastics. (7-2)
2. Plastic sheets are cut by using ordinary hand, hack, band, circular, or jig saws. (7-5)
3. Become milky or cloudy. (7-21)
4. By using masking material. (7-32)
5. They will be removed and replaced. (7-39)
6. Laboratory tests show that sanding of the surfaces to be cemented is essential to insure an adequate (satisfactory) joint strength. (7-61)
7. Annealed following forming or machining. (7-62)
8. Annealing of plastic consists of prolonged heating at an elevated temperature followed by a slow cooling. (7-68)

Section 8

1. The methods for forming laminated plastics are the "flash heating" and "controlled forming." (8-6, 7)

Section 9

1. The best cement for joining cellulose plastic is the solvent type. (9-2–4)

Section 10

1. Canopy covers are removed by lifting the cover off the surface and not sliding across the surface. (10-3)

Section 11

1. The canopy is protected by cutting a sheet of polyethylene film to match the surface of the canopy and then tape the sheet to the edges of the canopy with 2-inch wide masking tape. (11-1–3)

Section 12

1. Never force a panel out of shape to make it fit. The panel must fit loosely or obtain a new one. Fitting and handling must be done with the masking paper in place. Allow for dimensional changes along with temperatures. Use clamp mounting to distribute stresses. Use a jig or fixture to hold the frame in shape. Follow the procedures in the applicable technical order. (12-2, 3)
2. It is important that glass and plastic enclosures are installed correctly to prevent internal stresses. Stresses in glass or plastic panels will cause crazing, cracking, or possible distortion. (12-2, 3, 23)
3. Improper torque will cause stresses in the glass and plastic panels, which will cause crazing in plastics and possible cracking of both glass and plastic. (12-2, 3, 23)
4. Obtain a new replacement or sand the panel to obtain the exact size to conform with the mounting frame. (12-2, 23)
5. First select the applicable technical order for procedures and sizes of fasteners, etc. When no directions are given, use oversize spacers, shoulders, and stop nuts. (12-3, 4, 23)
6. Remove all old sealants by scraping with a phenolic or hardwood material. If you have difficulty, apply a stripper compound, then apply an approved solvent. Before sealing, reclean with aliphatic naphtha. Mix sealant according to directions on the container and apply with putty knife, or by injection, faying, and filleting methods. Aerodynamic smoother requirements are the same as sealants for cleaning. The compounds must be thoroughly mixed. They are applied with a spatula and spread evenly over the area. Force into slots, holes, and openings. After it has cured, it can be sanded or filed for flushness with the surface. (12-7; 9-16)

CHAPTER 2

Section 13

1. Mat molded fiberglass is made by using a fiberglass mat saturated with a resin mixture and cured with or without heat. The mat is made from fiberglass strands of different lengths. When you look at the mat molded fiberglass, you will see the chopped strands of various lengths, from approximately ½ to 2 inches long, embedded in the hard plastic. The strands are in a random pattern. (13-3, 8, 25)
2. PVA film are used mostly with polyester resins as a parting agent. It is water soluble and can be easily removed from the repair. The film curls and will stretch when heated so all wrinkles can be smoothed out and will follow any contour surface. Cellophane, another parting agent, is used mostly for epoxy resins. It will not stretch, it will wrinkle, and heat will cause it to harden. It is used on flat surfaces and on single contours. (13-6, 7)
3. Resin, catalyst, and accelerator must be measured by weight to insure that the correct proportion of each ingredient is used for the mixture. The addition of too much of any one would not allow the mixture to cure properly. Too much catalyst will cause the resin to crystalize. (13-9–13)
4. Mix the accelerator in the resin very thoroughly, then add the catalyst. Mix the ingredients thoroughly and saturate the fiberglass mat. Never mix a catalyst and accelerator together as an explosion may occur. Protect your skin, wear rubber gloves, face shields, or goggles. When handling resin impregnated materials and solvents, wash with soap and water frequently to prevent irritations of the skin and infections. Work in a well-ventilated room and do not breathe or inhale fumes from the chemical mixtures. (13-9–11, 13, 26)
5. The resin used for fiberglass repairs comes in a liquid form. It cannot be used in a repair in its original state but must have other chemical material added for it to become hard. The accelerator is a chemical compound needed to speed up the chemical reaction caused by the addition of the catalyst. The catalyst is a chemical compound added to the resin mixture to start a chemical reaction needed in the curing process. (13-9–11)

[illegible]. Resin and catalyst taken from a refrigerated storage place are left to warm to room temperature before using or mixing. Resin and catalyst have a shelf life: do not use outdated materials, as an uncured repair could result. Remember, follow the technical order procedures. Measure correctly all ingredients and mix thoroughly to have a good repair. Again, never mix the catalyst and accelerator together. Prevent an explosion. Prevent skin irritations and possible infection by wearing the proper gloves, goggles, and wash with soap and water frequently. (13-9–13, 26)

Section 14

1. (1) Taffeta (plain weave)
   (2) Basket weave
   (3) Crawfoot satin weave
   (4) Twill weave
   (5) Leno weave
   Structural property of fiberglass cloth is strength and with it is the weave, along with weight, thickness, finishes, and strength of the strands. (14-2–4; Fig. 8)
2. The soft spot is an indication of a delamination. Damages of less than 3 inches in diameter are allowable and can be repaired. The repair procedures are given in paragraph 10-20 (see chart 1). (14-10, 23, 24; Chart 1)
3. Minor repairs to laminated fiberglass are made by lightly sanding and cleaning the damage area. Mix resin according to applicable technical order. Apply resin mix to level of the surface. Cover with PVA film or cellophane. Work out air bubbles and excess resin and cure the repair. Remove all excess resin by sanding. (14-10, 19; Chart 1)
4. To pressure cure a repair, lay a continuous strip of putty (Duxseal) around repair. Place tubing and vacuum hose near the wet laminate and seal in putty. Place a piece of cellophane or PVA film over repair and seal in putty. Apply vacuum slowly (vacuum causes atmospheric pressure to push film against repair). (14-14)
5. The cause for the repair not curing in 1 hour was probably that the surrounding air was colder than room temperature of 70° Fahrenheit. Air was blowing over the repair, reducing the heat from the lamp. (14-15)
6. The cause of ply separation was probably due to improper cleaning of the area with MEK and not thoroughly drying the surface. Another cause is touching of the surface with your hands, which leaves oils on the surface. The threads seen in the resin were caused by not cutting the saturated cloth between two pieces of cellophane or PVA film. (Cutting between two pieces of film prevents fraying of edges.) (14-20–22)
7. The surface finishing of laminated fiberglass is necessary to obtain a smooth finish and to remove excess resin. Excess resin can cause degrading of the radar system. The laminates must be within the tolerance of drawings. (14-22, 24)
8. The repair shall be of good workmanship. The requirements for laminated repairs are as follows: Minor defects are allowable if they do not exceed specific specifications and are within the allowable limits as given in the applicable technical order. The laminate shall be within tolerances of drawings and specifications. Each layer of fabric shall be butted against existing ply. Wrinkles are not allowed. Blisters and delaminations are allowed if within the limits specified by the technical order. The repaired surface must be free of tackiness and properly cured to hardness required. The inspection consists of visual and metallic ring tests. Hardness test. The electrical testing method is done by qualified personnel from the proper organization after the part is repaired and when required. (14-24, 25)

Section 15

1. When honeycomb core is damaged, it is necessary to replace it with another core of the same material thickness, configuration, cell size, resin type, etc. The composition of material must have good dielectric qualities for radio and radar transmission. The core stabilizes the outer facings. To maintain their strength, the cells must not lose their shape and arrangement between the two facings. The steps in repairs were planned with the purpose to equal as near as possible the strength of the original part, without increasing weight, reducing aerodynamic smoothness, and electrical properties. When procedures are followed, good bonding of materials is assured with an acceptable repair. (15-1–3, 16, 17, 24)
2. The construction features of fiberglass honeycomb core materials are: The core is used to separate outer and inner facings to obtain a high bending stiffness. The core keeps the facings elastically stable when highly stressed. This construction makes strong rigid parts with minimum weight. Core material is constructed of thin sheets of material to form honeycomb configurations. The most common core materials are made

of glass cloth impregnated with polyester or a combination of nylon and phenolic resin. They have very good thermal insulation characteristics. They are also noted for the dielectric constant, the loss tangent, and low rate of moisture absorption. (15-2–4)

3. Face plies and core material are inspected visually. Place the enclosure or part between yourself and a strong source of light. The transparency of the part will permit you to see defects in the core material. A substantial fillet of resin should be around each core interface. When resin is missing, check the area using the metallic ring test. Moisture detection is accomplished with a moisture indicator. Oil can be detected by a darkness in the part. (15-7, 9)
4. The reason for each step in the use of a moisture register during inspection of honeycomb radomes is to prevent erroneous and erratic readings. (15-9)
5. The repairing organization is the depot. Repairs made in the critical window areas of a radome will need electrical testing. Most field organizations do not have testing equipment, as most personnel are not qualified to perform all necessary testing. The purpose of electrical testing is to insure proper transmission of electronic signals. (15-14; 14-11, 27; Figs. 29, 30)
6. Each step is needed in repairs of outer coatings and facings to have good adhesion of coatings and bond of resin to materials for an acceptable repair and also to preserve the structural properties of the part. (15-24; 14-18, 21)
7. The steps in repairing of punctures are needed to assure a good bond between resin and materials. It is necessary to restore the part to its original strength. Keep out moisture and other contaminates. (15-24, 27)
8. To use a hardness tester on honeycomb structures, place the indenter over the supporting cell wall and exert light pressure against the instrument to drive the indenter into the material. Take several readings (at least five) and average them. A properly cured repair shall have a hardness of 55. (15-39; 14-25, 26)

Section 16

1. Fluted core radomes are of three-layer and five-layer construction. They have anti-icing ducts, also called flutes. The flutes are connected to a hot air source. The flutes allow air to circulate through the ducts for anti-icing purpose. (16-1)
2. Each step is needed in the removal of damaged flutes because as damaged material is removed the surfaces are being prepared for the replacement of new materials. (16-3; 14-16, 20)
3. Replacement of flutes in a radome is necessary when the damage is into or through the ducts. Air leaking through a flute can cause delamination of other parts. Each step is necessary in the repair to maintain strength, contour, and to assure a well-bonded repair. (16-3, 5, 6)
4. The repairs to fluted core radomes are repaired in the same manner as the honeycomb core radomes. The only difference in repairs is the repair to the flutes. The flutes can be manufactured or purchased for replacement, whereas the honeycomb core must be purchased and cannot be made in the shop. (16-5, 6)

Section 17

1. Foam core material in fiberglass structures is repaired when damage extends into or through the core material. The core acts as a reinforcing material for structural parts. The part must be repaired in accordance with the applicable technical order and treated as a structural part. Each step in the repair is needed to assure a good bond, strength, and maintain structural properties. Foamed core radomes electrical properties must be maintained in accordance with the applicable technical order. (17-1, 2, 7)
2. The construction of foam core fiberglass radomes are manufactured to very close tolerances on overall thickness, including the facings and core material. The cores are developed by pouring resin between two facings of fiberglass. (17-2)
3. The repair and inspection of foam core radomes are similar to honeycomb core radomes, with one exception, such as replacement of core materials. Honeycomb material is manufactured, whereas foam core can be produced by mixing two or three liquids together and poured into the cavity. A cured foam plug can be made and fit into the cutout core area. The repair of facings are the same as for honeycomb fiberglass repairs. (17-6, 7, 10)
4. The mixing of plastic foam materials is very simple. Two components are poured together and mixed. They must be mixed thoroughly for a required time, then poured into the cavity. It is best to mix components at room temperature. (17-6, 8, 14)

Section 18

1. Handle enclosures and parts with care. Always place them on a padded dolly or surface. (18-1, 2)
2. The airman should have placed the enclosure on a padded surface. Scratches or any damage to the facings could result in hampering radar or radio transmission and receiving. (18-1, 2)
3. Each step is needed in repairing of predrilled holes in fiberglass enclosures to assure a well bonded part and that stresses will be carried over the part. (18-2; 14-20)
4. Sanding or shaving fiberglass enclosure edge bands is permitted if you do not sand into the fiberglass cloth. When sanding or shaving into or through the fiberglass cloth plies, it shall be treated as a Class I repair. (18-3)
5. Sealing of areas where water may seek its way into an aircraft shall be sealed in accordance with the applicable technical order. Areas such as bolts, rivets, and hardware parts are most susceptible to water leakage. Aerodynamic smoothing compound is applied to areas where smoothness of airframe is needed. Technical orders will give you the critical areas. Any deep depression or dent is filled with smoothing compound to maintain surface smoothness. (18-4, 5, 6)

CHAPTER 3

Section 19

1. The superior strength-to-weight ratio of metal bonded honeycomb panels over conventional structures would be the most logical reason for selection of this type of construction for installation in a specified area. (19-2)

Section 20

1. Sonic vibration damage is usually a delamination or separation of the core and face along the bond line. (20-2)
2. The inspection of metal bonded honeycomb panels must be more critical than that for conventional structures, because a metal bonded assembly can suffer extensive damage without any observable indication. (20-2)
3. A metallic ring test, spur wheel, and use of the coindascope are three additional methods used to test metal bonded honeycomb panels for delaminations. (20-4, 6, 12)
4. A caustic soda solution. (20-8)
5. The applicable section of the –3 TO for the B-52G contains a damage evaluation chart. This chart gives you the necessary information as to specific types of damage, allowable damages, damages requiring repair, and figure numbers that illustrate similar repairs for each type of damage. (20-17)

Section 21

1. The primary tool used to remove damaged material from metal bonded honeycomb panels is a pneumatically powered, hand-operated router with speeds ranging from 10,000 to 20,000 rpm. It is used in conjunction with the support assembly, bit, and template. (21-3)
2. You must turn the router support assembly approximately 6 turns to cut out a 0.500-inch damage (6 × 0.083 = 0.498). (21-3)
3. A locally manufactured router template or a multitemplate could be used to insure the removal of the exact diameter of material from a damaged area. (21-3)
4. You must give close attention to inspecting the damaged area and be extremely careful in evaluating the extent of the damage to be removed. (21-6)
5. The bent or closed aluminum core cells should be opened, straightened, or trimmed by using tweezers or a penknife. (21-6)
6. Pressure jigs are used to apply pressure to repairs on the undersurfaces of honeycomb panels or assemblies in order to hold the repair materials and resins in place. (21-7)
7. The correct proportions of epoxies, resins, and microballons are measured by gram weight with the use of a balance scale. (21-10)
8. Use infrared heat lamps to shorten the drying or curing time for metal bonded honeycomb repairs. (21-11)
9. An explosive meter is used to detect and indicate the intensity of combustible gases. It would be used any time you are required to work in any area suspected of containing explosive fumes. (21-14)
10. Equipment, materials. (21-16)
11. It is particularly necessary to observe all fire precautions when making metal bonded honeycomb repairs because of the low flash point of the repair materials. (21-17)
12. Methyl ethyl ketone is usually effective in cleaning operations. (21-21)
13. A water break test is a test performed to determine whether an area is completely and throughly clean. This test is a simple application of distilled water to a cleaned area. Any break of the film of water indicates that the area has not been cleaned thoroughly and the cleaning process must be repeated. (21-24)

14. Primers are applied to the cleaned surface areas primarily to insure a good bond of the honeycomb repair materials. (21-25)
15. The ingredients used in the adhesive mixture for glass fabric cloth overlays are Epon 812, Epon 828, Versamid 115, and Versamid 125. The mixture is composed of equal parts of Epon 812 and Epon 828 mixed with an equal mixture by weight of Versamid 115 and Versamid 125. (21-27)
16. The ingredients used in the mixture for a potted compound repair are Epon 815 (low viscosity liquid resin), curing agent T, and microballoons. (21-28)
17. Fiberglass honeycomb core materials are used to replace damaged aluminum core materials, because the aluminum core materials are not satisfactory for repairs due to their flimsy and fragile construction. (21-29)
18. Two layers of number 181 glass fabric cloth are required for the repair of flat surfaces or metal bonded honeycomb panel. (21-30)
19. Four layers of glass fabric cloth number 181 are recommended for use in the repair of a transition area. (21-30)
20. Zinc chromate and aluminum pigmented Corrogard are recommended for use as erosion and corrosion preventives. (21-32)
21. The pieces of sheet plastic used in the potted compound repair provide a smooth surface effect, provide part of the reservoir for the hole-filling operation, and hold the potting compound in place until it is completely cured. (21-39)
22. The stem of material is removed or smoothed down by using a file, router, or microshaver. (21-44)
23. The soundness of a potted compound repair is tested by the metallic ring test method. If you hear a clear metallic ring when a coin is bounced against the repair area, the repair is sound. (21-45)
24. A glass fabric cloth overlay repair would be made to an area 2 inches in diameter, since the maximum allowable hole that can be repaired by using potting compound is 1 inch in diameter. (21-50)
25. The glass fabric cloth overlay laminates should be 6⅛ inches in diameter when ready for application (1½ inches beyond the edges of the damage cutout). (21-52)
26. A bridge is used to position the router template in a transition area so that it is perpendicular to the core cells and parallel to the lower facing. (21-55)
27. Glass fabric cloth number 181 is preferred for repair of transition areas because of its flexibility and ease of application. (21-56)
28. Damage Evaluation Chart - Honeycomb Structure in the applicable --3 technical order. (21-59)
29. Adding or applying potting compound to the edges of core material is called buttering the core. (21-63)
30. It is important that the area be thoroughly cleaned in order to insure a good bond between the repair materials and the panel. (21-68)
31. True. (21-70)
32. Techniques used for the removal of damaged honeycomb skin and core material differ because of the construction features of the panels, location of the damage, and the fact that the honeycomb core is always installed with the cells perpendicular to the lower surface. (21-73)
33. The excessive potting compound is removed with a plastic scraper and the surface area thoroughly cleaned with MEK. (21-75)
34. This is to insure the core plug is firmly in place before any further repair steps are made. (21-75)

Section 22

1. The factors to consider when inspecting a completed repair are maintaining original strength, keeping weight to a minimum, maintaining original contour, and preventing corrosion. (22-1)

CHAPTER 4

Section 23

1. The push rod installation would be more apt to break because it will not flex as easily as the cable, will work-harden with use, and cables of the same size as push rods are stronger. (23-3)
2. Regular lay is most commonly used in cable construction because it will not set or stretch as much as other types of cable construction. (23-5, 6)
3. Cable strands are preformed (1) to obtain flexibility in the cable, (2) to relieve bending and twisting stresses, and (3) to keep the cable from spreading when cut. (23-7)
4. A 7 x 7 (1 WRC) cable is one that has six strands wrapped around the center. (23-10)
5. The location of the broken wires and their number determine the allowability of the broken wires in a cable. (23-12)
6. The corrosion must be present in the interior strands of the cable to make replacement necessary. (23-13)

7. A balltype cable fitting serves as a stop. (23-18)
8. A clevis fitting is used to fasten a cable to an actuator. (23-21)
9. A turnbuckle is used to adjust tension of a cable. (23-29)
10. Fair-leads are installed to reduce vibration in long lengths of cable. (23-34)
11. A tensiometer would be used at any time the tension in a loaded or stressed cable had to be measured. (23-42)
12. You should not use a torch to cut a cable. (23-45)
13. The elongation of the terminal must be considered in the fabrication of cable assemblies to assure proper length. (23-49)
14. You should check to make sure all additional fittings and accessories are slipped onto the cable in their proper sequence before swaging the terminal to the opposite end of the cable. (23-53)
15. Never use a corrosive flux when sweat-soldering terminals. (23-56)
16. The first step in starting a wrap-soldered splice is to press the free end and the standing length of the cable together tightly. (23-61)
17. Woven-spliced terminals may be used if facilities are limited and immediate replacement of the cable is necessary. (23-64)
18. The size of the cable, the terminal, and dies should be checked for identical sizes when using the Kearney swaging machine. (23-67)
19. Tested for proper strength before installation. (23-69)
20. A suitable guard should be placed over the cable being tested. (23-70)

Section 24

1. Stainless steel should be used for external brake lines. (24-11)
2. The three types of plumbing connectors are the flared, the bead-and-clamp, and the swaged type. (24-14)
3. Blue AN fittings are made of aluminum alloy. Black AN fittings are made of steel. (24-17)
4. By using code bands of colored tape which are placed around the lines at various points. (24-22)
5. Damage longer than one union in high-pressure lines requires a major repair. (24-27)
6. Beaded type fittings may be used in the repair of low-pressure lines. (24-29)
7. Due to the fire hazards caused by leaks and the importance of maintaining sufficient operating line pressure. (24-32)
8. A section of tubing cannot be cut and flared so accurately that it can be installed without bends and still be free from initial mechanical strain. Too, bends are necessary to permit the tubing to expand or contract under temperature changes and to absorb vibration. (24-39)
9. Tubing should be cut with a fine-toothed hacksaw or preferably a tube cutter. (24-43)
10. With care, tubing of ¼-inch diameter or less may be bent by hand. (24-46)
11. The three-piece solderless union is used with the single or double flare. (24-55)
12. True. (24-65)
13. Either a torque, an open-end, or cutaway box-end wrench should be used for tightening plumbing fittings. (24-74, 75)
14. Completed plumbing repairs should be checked for proper fits, rubbing against other items, leaks, and correct identification color codes on the lines. (24-82)

STOP– 1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER. 2. USE NUMBER 1 PENCIL.

53450 04 24

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student. send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

40

Multiple Choice

Chapter 1

1. (400) The glass laminated enclosure is distinguished from the plastic laminated enclosure by

   a. lightly tapping the outer surface for a difference in sound.
   b. scratching the surfaces for hardness.
   c. looking for a synthetic fibre edge.
   d. looking for a nonheated window.

2. (401) Which method is best for storing formed parts made of acrylic plastic?

   a. Cover and support with a frame. Keep from solvent fumes.
   b. Protect from temperature of 120° Fahrenheit.
   c. Cover with masking tape.
   d. Cover with cloth.

3. (403) Use a moderate drill speed, feed slowly, and use light pressure when drilling plastics to avoid

   a. grabbing.
   b. breaking drills.
   c. slippage of plastic forms.
   d. elongation of frame holes.

4. (400) Thermoplastic materials can

   a. be formed with heating.
   b. be reheated and reformed.
   c. be formed using water pressure.
   d. not be reheated or reformed.

5. (400) Acrylic plastics are used for enclosures because of

   a. ease of manufacture.
   b. their low cost.
   c. high transparent properties, strength weight, and forming ability.
   d. their resistance to radiation.

6. (401) You are to clean a transparent plastic enclosure. You should dust with

   a. clean cheesecloth.
   b. clean cloth and cleaner.
   c. auto polish and cleaner.
   d. a clean, soft cloth saturated with water.

7. (401) Plastic sheets should be stored with

   a. masking tape removed.
   b. masking tape in place and in bins tilted at 10° angle.
   c. cured side down.
   d. edges away from heated area.

8. (402) The best procedure to use for finding leakage of air in a laminated plastic windshield would be to

   a. remove and replace canopy.
   b. check the applicable technical order.
   c. look for bubbles in the windshield.
   d. visual check for milky appearance and separation of inner or outer face ply.

9. (400) There are three types of transparent plastics. Which is the most common one used on aircraft today?

   a. Synthetic.
   b. Cellulose.
   c. Acrylic.
   d. Thermoplastic.

10. (400) The plastic industry began about

    a. 1870.
    b. 1906.
    c. 1930.
    d. 1954.

11. (402) Using the drawing in VRE Figure 1 of damaged transparent plastic panels, identify the drawing that best illustrates crazing.

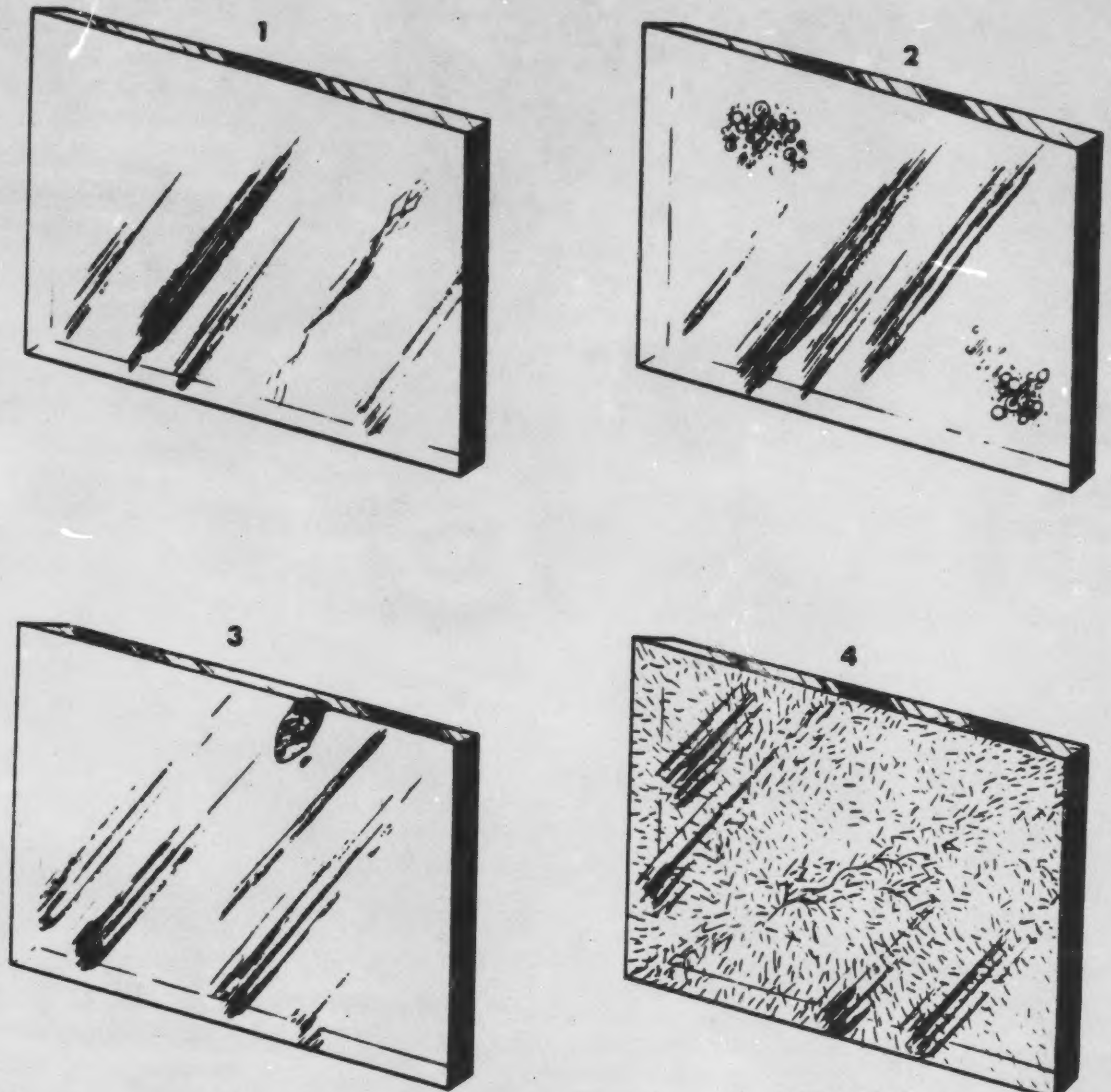
    a. 1.
    b. 2.
    c. 3.
    d. 4.

12. (405) Once a plastic assembly is placed in a jig after cementing,

    a. it is never inspected.
    b. water is used to aid in setting up repair.
    c. the joints should be examined at intervals.
    d. it is removed and tested every 20 minutes.

13. (404) Ashing plastics is a very popular substitute for

    a. filing.
    b. sanding.
    c. brazing.
    d. heating.



53450—4—1—VRE—1

Volume Review Exercise Figure 1.

14. (404) A fan or other means of forced circulation of air is used in a plastic heating oven to

    a. speed up the heating operation along the edges of plastic.
    b. maintain a uniform temperature throughout the oven.
    c. heat only transparent plastics.
    d. reduce the fabrication cost.

15. (406) To condition a sheet of cellulose plastic for machining, one must

    a. anneal the plastic.
    b. condition it to a normal temperature for 24 hours.
    c. heat the part for 24 hours at room temperature or above.
    d. condition it to a temperature ranging from 80° to 90° Fahrenheit for 24 hours.

16. (401) After a plastic surface has been cleaned and no scratches are present, apply
    a. a light engine oil to bring out the gloss.
    b. MEK to inner surface to prevent dust from forming.
    c. one or two coats of an automobile wax to produce a surface gloss.
    d. hydraulic fluid to outer surface to protect it from the sun's rays.

17. (406) Why is laminated plastic more difficult to form than acrylic sheets?
    a. Inner layer material will soften.
    b. Forming temperatures are different.
    c. Unbalanced laminates will crack when formed.
    d. Properties of inner layer are not the same as outer layers.

18. (404) Why should soft cotton gloves be worn when removing heated plastic from the oven?
    a. To reduce overall cost.
    b. To prevent edge damage to the heated plastic.
    c. To prevent damage to the heated plastic surface.
    d. Because leather gloves are harder to obtain than soft cotton gloves.

19. (407) Which of the following is the recommended procedure for removing sealants from a retaining frame?
    a. Scrape material with a spatula.
    b. Reapply a stripper compound.
    c. Use a sharp knifelike tool made of phenolic.
    d. Use a sharp knifelike tool made of aluminum.

20. (407) You are about to install a transparent enclosure into a retaining frame. You received the enclosure from the warehouse which is not heated, and the temperature is 0°. After checking the frame, you noticed some sealant has been left in the extruded part. The procedure to follow is
    a. order a new enclosure.
    b. heat the plastic and then install in the frame.
    c. install at normal temperature, clean frame with methyl ethyl ketone, wipe dry, and clamp down.
    d. remove old sealant from frame, reclean with aliphatec naphtha, wipe dry, and in stall at normal room temperature.

21. (407) To insure using the correct hardware in installing transparent panels, use
    a. bolts and the correct length rivets.
    b. the manufacturer's recommendations.
    c. a drill jig to hold the frame in place.
    d. spacers, bolts, collars, and stop nuts that do not interfere with other parts.

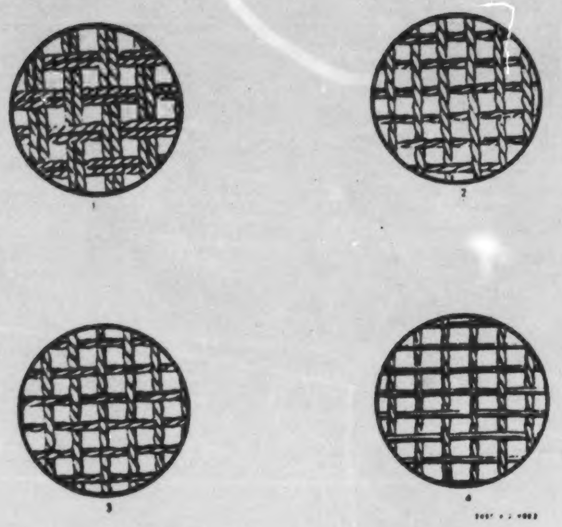
22. (406) When painting around acrylic plastics,
    a. remove the plastic assembly from the painting area.
    b. cover the plastic surface with aluminum foil.
    c. cover the plastic surface with a primer.
    d. cover the plastic surface with a lacquer.

23. (407) You are sent to install a plastic window in an aircraft. You have to drill holes in the window to fit the retaining frame boltholes. You select a drill the same size as the bolts that hold the window in the frame. After drilling the holes in the window, you start to install the window in the frame and begin tightening the nuts successively around the frame until you realize you are installing it incorrectly. Select the correct method for installing the window.
    a. Remove masking paper before installing and polish.
    b. Use spacers and shoulder bolts and ream all the holes.
    c. Seal the window before installing in the frame and apply smoothing compound.
    d. Drill the holes larger than the bolts being used and tighten nuts diagonally back and forth across the window.

Chapter 2

24. (408) What would happen to your mat molded repair if you increased the amount of catalyst from 2 parts to 3 parts?
    a. Resin would become hard.
    b. Repair would not cure properly.
    c. Curing time would be shortened.
    d. A chemical reaction would take place.

25. (409) Using the drawing in VRE Figure 2 of weave patterns for fiberglass, identify the drawing that illustrates a plain type weave.
    a. 1.
    b. 2.
    c. 3.
    d. 4.



Volume Review Exercise Figure 2.

26. (408) You are preparing a resin mixture to repair a hole in a mat molded fiberglass part. In the repair mixture given below, which of the parts should be put into the mixture last to prevent a possible violent reaction?
    a. Resin per MIL–R–7575, 67 parts by weight.
    b. Promoter cobalt naphthenate, 0.5 by weight.
    c. Fiberglass mat binder, ½ inch squares, 33 parts by weight.
    d. Methyl-ethyl-ketone peroxide liquid catalyst, 2 parts by weight.

27. (413) An object pierced the inside of a radome facing at station 97.5 and 8 inches below the water line. The hole is ½ inch in diameter. The core is damaged to a depth of ¼ inch. Determine the class of repair and who will make the repair.
    a. Class I repair, to be made by the depot.
    b. Class II repair, to be made in the field.
    c. Class II repair, to be made by the depot.
    d. Class III repair, to be made by the depot.

28. (411) When making a fiberglass laminate repair by the stepped joint method, the *incorrect* method is to
    a. use a knife and cut through outer ply.
    b. remove outer ply and each successive ply and replace with similar material.
    c. scribe on exposed ply a similar outline reducing the dimension 1 inch.
    d. lightly sand exposed plies, clean with MEK, and thoroughly dry the surface.

29. (408) You are to make a repair to a mat molded fiberglass part which has a hole ¾ inch in diameter and a crack 1 inch long extending from the hole. You will mix MEK peroxide liquid catalyst and promoter cobalt peroxide liquid into the resin. Classify the damage and why will you mix the promoter in with the resin prior to adding the catalyst?
    a. Major repair and to prevent an explosion.
    b. Minor repair and to prevent an explosion.
    c. Major repair and possible explosion with an uncured repair.
    d. Mixing the promoter and catalyst together will cause an explosion.

30. (408) You made a repair to a mat molded fiberglass junction box and the repair would not cure. You applied heat as required and included the correct kind of ingredients to the resin mixture. What could you have done wrong?
    a. Were inaccurate in measuring the mixture.
    b. Used a wooden paddle made of oak.
    c. Clamped the repair too tight.
    d. Used an aluminum paddle.

31. (414) During a PE inspection of a B52G aircraft, an inspection of the radome revealed a hole approximately ½ inch in diameter through the outer facing and honeycomb core. On further inspection for repairing, you discover another hole opposite the damage, approximately ⅛ inch in diameter. Determine the class and method of repair you will make on the part.
    a. Class II repair and scarf repair.
    b. Class II repair and step joint repair.
    c. Class III repair and step joint repair.
    d. Class III repair and scarf method of repair.

32. (408) Mat molded fiberglass is identified by
    a. fibers and color.
    b. short chopped fibers.
    c. molding mat fiberglass with resin.
    d. seeing fiberglass strands of various lengths, in a radome pattern, embedded in hard plastic.

33. (411) Minor repairs to fiberglass laminates are considered to be
    a. delaminations less than 3 inches in diameter with a perforation on the edge 1 inch in diameter.
    b. scratches, scars, minor rain erosion, and surface abrasions.
    c. dents which do not exceed 2 inches in diameter.
    d. cracks 1 inch in length.

34. (410) On inspection of a radome, you found a small depression which was approximately 1 inch in diameter; using chart 1, the type of damage is known as a

a. dent and can be repaired.
b. dent and cannot be repaired.
c. delamination and can be repaired.
d. delamination and cannot be repaired.

35. (413) You are inspecting a radome for defects and find a discoloration approximately 6 inches in diameter, and you also notice the fillets are missing around the core cells. What method would you use to determine if there is a defect in the radome?

a. Hardness test.
b. Metallic ring test.
c. Moisture indicator test.
d. Thumb and finger pressure.

36. (415) The flutes in a fluted core radome are made of

a. nylon.
b. nylon phenolic.
c. fiberglass cloth.
d. honeycomb material.

37. (410) A laminated fiberglass repair is vacuum bagged to

a. remove wrinkles and cure resin.
b. reveal air bubbles and cure resin.
c. apply pressure to resin surface and cure repair.
d. apply pressure to surface, remove air bubbles and excess resin, and cure repair.

38. (414) How would you repair a small puncture to the size of a pinhead in a radome?

a. Resin mix with milled fiberglass.
b. Make a step joint repair.
c. Mix resin with fibers.
d. Use resin only.

39. (415) The inspectors found a ½-inch hole through the facing and a flute of an enclosure. Each step is needed in the replacement of flute to

a. assure a good bond of parts.
b. carry major loads through the flutes.
c. maintain structural properties and prevent air leakage.
d. make a good-looking repair, maintain contour, and prevent air leakage.

40. (414) Each step in a honeycomb repair of outer coatings and first ply of honeycomb core fiberglass skin of a radome is needed to

a. prevent rain erosion.
b. preserve the structure.
c. stop rain erosion and preserve the structural properties.
d. help retain the structural properties and to make an acceptable repair.

41. (415) To repair a fluted core radome, remove the damaged material by starting

a. from the outside surface and progressing in stages toward the inside surface.
b. from the inside surface and progressing in stages toward the outside surface.
c. near a seam on the inside surface.
d. near a rib section.

42. (416) You are to repair a foam enclosure with a hole approximately 1 inch in diameter. The damage is through facings and core. The temperature is 105°. Name the class of repair and how you will repair the damage.

a. Class II repair and pour in epoxy resin.
b. Class II repair and pour foam mix into the cavity.
c. Class II repair, cure a plug from plastic foam, and cut to fit core hole.
d. Class III repair, remove facings and damage core, and pour in foam mixture.

43. (413) Radomes tested in the field, with or without erosion-resistant and antistatic coating, must

a. have a moisture reading of 25.
b. have a moisture reading of less than 15.
c. be tested every 3 years.
d. be tested only when installed on an aircraft.

44. (416) You are in a shop and ready to repair a fiberglass enclosure. The enclosure is on the concrete floor and you put it on the table so that it will be easier to work on. After you repaired it, you had to transport it to an aircraft. What precautions should you have taken when working on and transporting the enclosure?

a. Place the enclosure on padded surfaces.
b. Find a dolly to transport the enclosure to a hangar.
c. Place on a wooden table and let transportation haul the enclosure to the aircraft.
d. Spray the surface with a protective coating before repairing and transporting it.

45. (416) The one difference in repair of honeycomb and foam core radomes is that a

   a. cured plug needs resin on its sides.
   b. honeycomb core needs resin on all its sides for bonding.
   c. cured foam plug does not need resin on its sides for bonding.
   d. honeycomb core needs resin on its sides, but not on the top and bottom.

46. (416) You must fill a cavity in a repair with foam material. The materials are in a room where the temperature is 90°. What will result when you mix the components together?

   a. An explosion.
   b. Mixture will foam before it is mixed.
   c. The cells will become larger than specified.
   d. The foam will absorb moisture more readily.

47. (416) Foam cores in radomes are obtained by chemical reaction. What class or type would you consider them to be?

   a. Thermosetting.
   b. Thermoplastic.
   c. Gas-expanding plastic.
   d. Foamed-in-place plastic.

Chapter 3

48. (417) Sandwich construction consists of

   a. two layers of similar metals.
   b. a core bonded between two metal facings.
   c. aluminum core materials bonded only to one face.
   d. metals that must be heat treated prior to use on aircraft.

49. (418) Pressure jigs are used to

   a. cut down repair costs.
   b. make a better vacuum seal.
   c. keep the test panel aligned.
   d. apply pressure to repairs on the under surface of a honeycomb panel until the repair material is cured.

50. (417) Damage evaluation charts for the repair of bonded honeycomb assemblies are found in

   a. the applicable section of –3 technical order.
   b. only in the manufacturer's repair manual.
   c. Air Force Regulation 63–74.
   d. applicable supply catalogs.

51. (417) The panel inspection analyzer is used to inspect

   a. wooden panels.
   b. honeycomb panels.
   c. fiberglass panels.
   d. plastic panels.

52. (419) Primers are applied to the cleaned areas to

   a. prevent sealant leaks.
   b. prevent organic corrosion.
   c. aid in applying masking tape.
   d. insure a good bond of honeycomb repairs.

53. (417) A standard panel with the same type and weight adhesive used in the bonded panel to be tested

   a. must never be used to standardize the analyzer.
   b. must be used to standardize the analyzer.
   c. will always be coated with zinc chromate.
   d. should be sawed on a bias for best results.

54. (418) The router is used in conjunction with the

   a. adhesive mixing equipment.
   b. panel pressure plate assembly.
   c. support assembly, bit, and template.
   d. panel inspection analyzer.

55. (417) When testing for voids or delamination in the adhesive bond between the facing and core of the sandwich, use an aluminum tapping hammer weighing

   a. 1 ounce. c. ½ pound.
   b. 4 ounces. d. 1 pound.

56. (420) Pieces of plastic and Duxseal dam are used in making

   a. fiberglass repairs.
   b. 434 resin mix repairs.
   c. potting compound repairs.
   d. repairs in sealed areas.

57. (419) The two materials used on bonded honeycomb assembly repairs to prevent erosion and corrosion are

   a. MEK and Type A sealant.
   b. 181 resin mix and Versamids.
   c. fiberglass cloth and 428 Epon.
   d. zinc chromate and aluminum pigmented Corrogard (EC 843).

58. (420) The approved alternate to glass fabric overlay repair is to substitute

   a. two layers of cloth 128 for the filler and overlay layers.
   b. three layers of cloth 181 for the filler and overlay layers.
   c. three layers of cloth 128 for the filler and overlay layers.
   d. two layers of cloth 181 for the filler and overlay layers.

59. (421) Before inserting the core plug into the damage cutout, all contacting (faying) surfaces of the core plug and edge of the cutout must be

   a. covered with oil to insure a better fit.
   b. "buttered" with an application of epoxy resin 820.
   c. painted with a zinc chromate to prevent corrosion.
   d. "buttered" with an application of the potting compound.

60. (417) An instrument used in place of the tapping method (hammer) is the

   a. spur wheel.
   b. copper fork.
   c. spur gear.
   d. tuning fork.

61. (422) When repairing flat and tapered surfaces of damaged bonded honeycomb, thoroughly clean the surface area several inches away from the damage to insure

   a. better adjustment of the router.
   b. freedom from static electricity.
   c. less future corrosion problems.
   d. better attachment of templates or wedge blocks to repair area with double-backed tape.

62. (418) Double-backed tape is used to prevent the router template from

   a. causing galvanic corrosion.
   b. creeping or misalignment.
   c. causing static electricity.
   d. cutting into the damage area.

63. (420) Glass fabric cloth overlay repair methods will be applied to skin delaminations and cracks larger than

   a. 1 inch in length or diameter.
   b. ¾ inch in length or diameter.
   c. ½ inch in length or diameter.
   d. ¼ inch in length or diameter.

64. (420) Bonded honeycomb structure damages up to 1 inch in diameter may be repaired by

   a. stop drilling near the hole.
   b. using a special glass overlay patch.
   c. filling the hole with potting compound.
   d. covering the damaged area with a special epoxy mixture.

65. (421) Two layers of impregnated cloth number 181 (three if number 128) are used

   a. as a substitute for 158 glass cloth.
   b. as overlays for each surface of the repair.
   c. when 234 fiberglass cloth is not available.
   d. to repair all types of radomes.

66. (422) The two acceptable methods of repairing damaged skin and core materials on a B–52 bonded honeycomb panel or structure are

   a. resin and epoxy 336.
   b. octagon or diagonal metal patch.
   c. surface and skin metal overlay.
   d. potted compound repair and laminated glass fabric overlay.

67. (422) A core plug is cut slightly larger than the desired thickness and shape from a (3/16-inch cell size) fiberglass honeycomb core material and is

   a. pressed in for a tight fit.
   b. sanded to correct shape (tolerance ±.010 inch).
   c. coated with grease and pressed in for a tight fit.
   d. sanded to correct shape (tolerance ±.050 inch).

68. (421) When damage is removed from a panel in a transition area, the routing template must be

   a. held on by "C" clamps.
   b. positioned securely by jigs.
   c. bridged on one edge.
   d. grounded to the damaged panel.

69. (421) When making a repair to a corner of a bay where a compound (double contour is encountered, glass cloth 181 is preferred because it

   a. costs less.
   b. makes a more durable patch.
   c. is more flexible and easier to apply, as four layers of impregnated cloth are used.
   d. is more flexible and easier to apply, as two layers of impregnated cloth are used.

70. (422) Completed repairs are inspected to insure that

    a. cost was kept at a minimum.
    b. job was completed on schedule.
    c. all repair materials were used.
    d. original strength and contour were maintained; weight was kept at a minimum; corrosion prevention methods were used.

71. (421) The pieces of glass cloth for the overlays on a tapered trailing edge repair are cut

    a. at least 3 inches larger than the repair area.
    b. the same size of the repair area.
    c. 2 inches larger than the repair area.
    d. 1/16 inch larger than the repair area.

72. (422) The procedure for the removal of a damaged honeycomb cell area occurring to a tapered upper surface of a panel is different than that for a flat or lower surface because

    a. more damage must be removed.
    b. less damage must be grounded.
    c. the template must be grounded.
    d. the routing template must be bridged over the repair area.

Chapter 4

73. (423) The technical orders to consult when evaluating damage on control cables are

    a. 1-1-4 and 02-4-6.
    b. 1-1A-8 and the maintenance technical order for a specific aircraft.
    c. 1-8-1A and the maintenance technical order for a specific aircraft.
    d. 1-1-1 and 1-8-1A.

74. (423) Preforming cables during manufacture keeps the cable

    a. from spreading when cut.
    b. from corroding.
    c. from deteriorating.
    d. low in cost.

75. (424) A tensiometer is an instrument that is useful in measuring

    a. tension in a cable loaded to 30 pounds or more.
    b. tension in any loaded cable.
    c. tension in any stretched cable.
    d. precisely the amount of tension in a cable.

76. (426) Color codes for identifying plumbing are listed in

    a. TO 1-1-8.
    b. TO 1-1A-8.
    c. TO 1-8-1A.
    d. TO 1A-8-1.

77. (425) Prior to installing cables worked on locally, they should be tested against the minimum allowable breaking strength load at

    a. 100 percent.
    b. 80 percent.
    c. 60 percent.
    d. 40 percent paired with 102.

78. (425) Sweat-soldered terminals are used on

    a. all forms of stainless steel cables.
    b. all types of cables.
    c. flexible cables only.
    d. lightly loaded cables only.

79. (425) When applied properly, the swagged terminal forms a bond

    a. stronger than the cable.
    b. stronger than the terminal eye.
    c. weaker than the cable.
    d. equal to, but not stronger than, original equipment.

80. (427) When making repairs to tubing in the oxygen plumbing systems, always use a

    a. single flare.
    b. double lare.
    c. soldered union.
    d. single flare near the indicators.

81. (426) Before making repairs to any aircraft plumbing, it should be

    a. accurately identified.
    b. pressure checked.
    c. heat treated.
    d. annealed.

82. (427) If line fittings leak, always tighten them

    a. under pressure.
    b. when pressure is low.
    c. at ½ operating pressure.
    d. when there is no pressure in the line.

83. (426) Tubing used for fluids at atmospheric pressure or less must be tested for

    a. leak-tight qualities at all times.
    b. corrosion-resistant qualities.
    c. bursting strength.
    d. 90 pounds of pressure.

84. (427) If a flare is improperly made, it can be corrected by

a. more tightening.
b. adjusting the B-nut.
c. adjusting the inner sleeve.
d. none of the above.

85. (427) When installing a line assembly in an aircraft,

a. never apply compound to the faces of the nipple or flare.
b. apply compound to the faces of the nipple or flare.
c. apply compound only to leaky oil line flares.
d. apply compound to leaky oxygen line flares.

86. (427) Exceeding specified torques when tightening plumbing fittings will cause

a. less leaks.
b. damage to fittings.
c. less maintenance costs.
d. less corrosion in fuel lines.

87. (427) The ordinary production tube bender will accommodate tubing ranging from

a. 1- to 4-inch outside diameter.
b. ¼- to 3-inch outside diameter.
c. ½- to 1½-inch outside diameter.
d. ½- to 1½-inch inside diameter.

88. (427) Damaged tubing and lines should be replaced with new items

a. if it is cheaper.
b. every periodic inspection.
c. whenever possible.
d. every 6 months.

89. (427) What are the two types of support clamps?

a. Rubber-cushioned and bronze.
b. Rubber-cushioned and plain.
c. Plain and phenolic.
d. Aluminum and copper.

90. (427) Leaks in newly installed oxygen systems can be stopped by further tightening only when

a. it's a high-pressure system.
b. it's a low-pressure system.
c. it's in a high performance aircraft.
d. specified torques are not exceeded.

542

53450 05 7202

CDC 53450

AIRFRAME REPAIR SPECIALIST

(AFSC 53450)

Volume 5

Supervision and Training

2-3

Extension Course Institute

Air University

544

Preface

THIS IS THE fifth and final volume of the *Airframe Repair Specialist* course. In the first four volumes of CDC 53450, you studied the airman classification system publications, processing of material, ground safety, aircraft metals, corrosion prevention, and airframe repair tools and equipment, inspection and evaluation of airframe damages, repair layout principles, metal forming processes, structural repairs, fasteners, transparent and Fiberglas enclosures, metal bonded honeycomb, cables, plumbing, and control surface balancing.

In this volume there are two main purposes intended: (1) to inform you of your responsibilities and your role in the management and leadership of personnel; and (2) to inform you of your responsibilities in the inspection and maintenance of Air Force equipment.

In Chapter 1 we will discuss inspections and evaluations; factors involved in the inspection of fabricated and repaired items, inspections and evaluations to insure a safe operating airframe repair shop, the inspection of equipment both shop and individual, the inspection of personnel, inspection of supplies, and the interpretation and use of the findings of the inspections you perform. In Chapter 2 we will discuss optical alignment; the fundamentals of optics, telescopes, principles of operation of the telescope, sight levels, transits, auto-reflection equipment, the tilting dumpy level, and the optical micrometer as used in conjunction with the tilting dumpy level. In Chapter 3 we discuss management of personnel; basic personnel relations you will need to know to understand the thinking of your people. We will also discuss the supervision of personnel, including personnel evaluation, counseling, and performance reports, along with file maintenance and background for preparation of orders and SOPs. In Chapter 4 training is presented from the arrival of a newly assigned airman through the resources available for training to his actual training and recording of that training on the proper documents. We discuss the dual-channel concept of training, responsibility for training, actually conducting a training program, and the use of the CDC program package.

It has often been said that the primary difference between a military unit and a mob is the attitude of those involved pertaining to discipline and supervision. This volume can assist you in your training as one of the knowledgeable leaders.

After you have completed this volume, review the entire course before you take the course examination (CE). Remember, this CDC contains the knowledge requirements you need to pass the test for upgrading to the AFSC level for which you are training.

The numbers which appear on the figures in this volume (for example, 53450–5–1–1) represent the preparing agency's illustration file number.

If you have questions on the accuracy or currency of the subject matter of this text, or recommendations for its improvement, send them to Tech Tng Cen (TTOC), Chanute AFB, IL 61868.

If you have questions on course enrollment or administration, or on any of ECI's instructional aids (Your Key to Career Development, Study Reference

Guides, Chapter Review Exercises, Volume Review Exercise, and Course Examination), consult your education officer, training officer, or NCO, as appropriate. If he can't answer your questions, send them to ECI, Gunter AFB, AL 36118, preferably on ECI Form 17, Student Request for Assistance.

This volume is valued at 15 hours (5 points).

Material in this volume is technically accurate, adequate, and current as of September 1971.

Contents

Page

Preface iii

Chapter

1 INSPECTIONS AND EVALUATIONS 1

2 OPTICAL ALIGNMENT 12

3 PERSONNEL MANAGEMENT 44

4 TRAINING 55

Inspections and Evaluations

AFTER COMPLETION of any repair, you must perform a final inspection. Final inspections are made to determine whether or not repairs have been accomplished in accordance with requirements and specifications listed in the appropriate technical manual of structural repair. The inspections you perform are not to be confused with those made by an authorized inspector; yours are simply checkpoints to assure that repairs are made properly before the aircraft is declared to be in serviceable condition. These final checks often turn up discrepancies which were overlooked and which might cause additional damages.

2. The most important factors in repair and those of which you should be constantly conscious are:

- Maintaining original strength.
- Keeping weight to a minimum.
- Maintaining original contour.
- Preventing corrosion.

3. These inspections can be embarrassing or they can be pleasant; how you feel about them is mostly up to you. If you are alert and apply yourself, there will be few, if any, defects in your work; you can be justly proud of a job well done. Your supervisor will appreciate it, too, for you will have increased his faith in your ability and also will have provided him with more time to devote to his other duties.

4. The aim of this chapter is to assist you in performing inspections. We devote the first portion to the inspection of parts and repairs that require your inspection prior to putting the part or unit back into a serviceable condition. In the following sections of this chapter we discuss the supervisory aspects of inspections; i.e., preinspections to determine the need and requirements prior to beginning actual airframe repair work.

1. Factors in the Inspection of Fabricated and Repaired Items

1-1. There are many factors which you must keep in mind when you are inspecting fabricated and repaired items. Among the more important such factors are the tools of inspection, the strength factor, the weight factor, the contour factor, corrosion detection, and comparison of the inspected items with drawings and specifications.

1-2. **The Tools of Inspection.** The tools of inspection are few. The inspector checks by sight, feel, and measurements. To do this, however, he must have the knowledge and experience gained through much study and practice. The standard tools for inspection are:

- Flashlight—Used to illuminate dark areas.
- Mirror—Used to look into areas where you ordinarily could not see. Sometimes a handle is attached so the mirror can be used in much the same way a dentist uses his mirror to look at your teeth.
- Six-inch scale—Used for measuring such things as rivet pitch, edge distance, and shop heads.
- Micrometer—Used for making precision measurements such as thickness of skin or members.
- Feeler gage—Used for checking loose rivets.
- Grease pencils—Used for marking defects discovered during inspection.
- Pencil and pad—Used for making notations of the findings.

1-3. **The Strength Factor.** Strength is normally the most important factor for you to consider when you are inspecting repairs made to damaged aircraft. The original strength must be returned to structural members if the aircraft is to be considered in good repair. Points to consider in maintaining strength are (1) correct gage and composition of materials; (2) proper size, type, and installation of fasteners; (3) heat treatment, and (4) cutout radius and edge distance.

1-4. *Correct gage and composition of materials.* It is vital that the correct gage and composition of materials be used in making repairs, since these two factors are of the greatest importance in the process of restoring strength to the aircraft. Consequently, the airframe repairman cannot afford to guess when selecting materials for repairs. Even though he will ordinarily know whether the damage is in a highly stressed area or not, he will not know the actual material strength measurement. The use of a repair piece which has less strength than the original could cause failure of the part.

1-5. To avoid such failure when making aircraft repairs, the airframe repairman should use the same gage and composition of materials as those which were used originally by the manufucturer. Note that the use of the same gage is not enough in itself—the composition and temper designation must also be the same.

1-6. It is sometimes permissible to substitute a metal of greater strength for one of lesser strength if there is no appreciable difference in weight and provided no *corrosion hazards* are involved (such hazards as occur when dissimilar metals corrode or when unclad materials are substituted for clad materials). When making final inspections, always consult an approved metals interchangeability chart, if substitutions have been made.

1-7. *Size, type, and installation of fasteners.* Insert or patch repairs must not be greater than the limits established in the technical manual of structural repair for a specific aircraft. Classification of damages must be correct in order to maintain the strength of the aircraft through repairs suggested by the classification. Rivets and bolts must be of the type, size, and condition specified by repair drawings or must be a specified allowable substitute.

1-8. The height of the shop head of a rivet should be one-half of the shank diameter, and the diameter of the shop head should be one and one-half times the diameter of the shank. If there is any appreciable deviation from the rule, the rivet should be removed and replaced. The condition of the shop head is also important if the strength is to be maintained. The head should be uniform in size and evenly bucked with a smooth bucking bar. If shop heads feel rough or sharp on the edges, they were probably driven too slowly and became work hardened before the riveting was complete. These rivets do not have maximum strength and should be removed and replaced. If the manufactured head has been damaged by the rivet set, the strength cannot be considered adequate in stressed areas.

1-9. Rivets must be of the same composition as those used by the manufacturer. A larger diameter is sometimes permissible, provided too many of them are not used, but a smaller diameter rivet must never be used as a replacement or a substitute. Head styles are also important, since different head styles provide varying degrees of strength.

1-10. When inspecting the installation of bolts, some of the things to look for are (1) correct diameter to assure a tight fit, (2) correct composition of the bolts, (3) correct grip length, and (4) correct installation. In connection with (4), for example, threads should not bear into the material which is bolted.

1-11. *Heat treatment.* Aluminum alloys used for stressed area repairs must be of the type which can be heat-treated. It is often necessary to use annealed aluminum alloys or to anneal heat-treated alloys in order to form complicated parts. Part of the job of inspecting finished repairs will be to see that these parts have been returned to the correct heat-treated condition after they have been formed and before they have been installed on the aircraft.

1-12. *Cutout radius and edge distance.* When aluminum alloys are formed or when damage cutouts are made, it is necessary to have a radius on inside corners in order to prevent the creation of a highly stressed area, at the point of the bend or at the corner of the cutout. Figure 1 illustrates both the concentration of stresses in the absence of a corner radius and the relief of stresses by locating a relief hole at the intersection of two flanges.

1-13. The strength factor can be influenced quite easily by improper allowance between the rivet and the edge of the material. Corner radii are, in most cases, the same as the edge distance from the center of the rivet to the edge of the

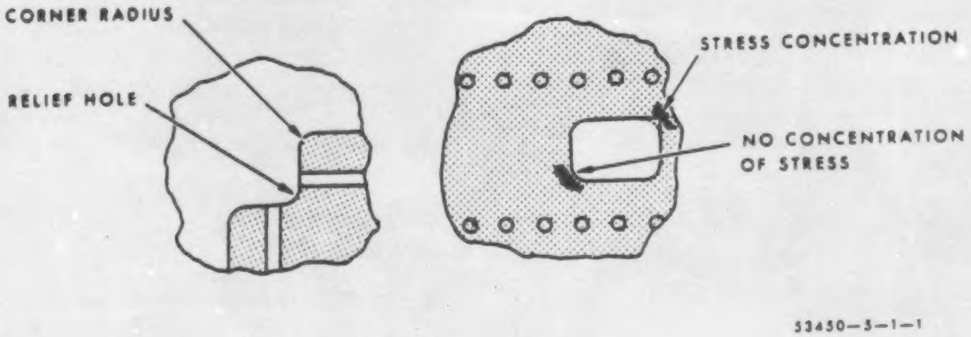


Figure 1. Stress relief.

material. Recommended edge distance is 2½ times the diameter of the rivet; minimum and maximum edge distances are established at 2 and 4 diameters respectively.

1-14. It is interesting to note that all rules for rivets, edge distance, corner radius, bend radius, relief hole diameters, and pitch are determined either directly or indirectly by the thickness of the material being used. For example: (1) the diameter of a rivet is usually 3 times the thickness of the sheet to be riveted; (2) edge distance, 2½ times the rivet diameter; (3) corner radius, usually the same as edge distance; (4) rivet pitch, 6 to 8 rivet diameters; (5) transverse pitch, ¾ pitch distance; (6) minimum bend radius 3 times the thickness of the material for hardened aluminum alloys; and (7) minimum relief hole diameter, the same as minimum bend radius. The one exception to these rules is this—in rivet pitch and transverse pitch, use the manufacturer's pattern when possible. During inspection, other factors which must be considered are weight, contour, and corrosion. We will discuss them in this order next.

1-15. **The Weight Factor.** The delicate balance of the modern aircraft approaches that of a timepiece. Thus, the addition or subtraction of weight as a result of repairs can have a very definite effect on flight characteristics. For this reason the airframe repairman must not permit his repairs to exceed additional weight limits allowed for specific repairs. Consequently, you should be weight conscious at all times when you are making repair inspections.

1-16. **The Contour Factor.** When making repairs, you must keep the shape of the different parts as close as possible to that of the original. To do this, check parts against the damaged parts to be replaced or against duplicate structures in the aircraft. Contour is especially important on the outer surfaces of the aircraft and on inner surfaces—such as those of bulkheads, ribs, and formers, all of which transfer their shape to the outside skins.

1-17. As an illustration of the importance of the contour surface on the high-speed aircraft of today, a few scratches and scuff marks on the wings, such as those caused by someone's walking on them, can decrease the airspeed. Furthermore, a flat place or hump could have even a greater effect on the speed and performance of the aircraft. Consequently, you should always check the contours closely when you are making final inspections.

1-18. **The Corrosion Factor.** Any type of corrosion, especially that occurring between dissimilar metals, which was discussed at length in a previous volume, is accelerated by the presence of moisture. Therefore, good places to look for evidence of corrosion are around rivets, around joints in the metal, in crevices where dirt and cleaning compounds may collect, in highly stressed areas, and where unlike metals come into contact or are separated by a water-absorbent material, such as wood, fabric, or sponge rubber.

1-19. Any time two pieces of aluminum alloy are fastened together, even though they are of the same composition, they should have coatings of zinc chromate primer on the contacting faying (joining) surfaces. Precautions should be taken to remove all metal chips, such as those which might be caused by drilling operations, to allow for close fit of the materials and to prevent scratching.

1-20. Scratches which penetrate the cladding on aluminum alloys should not be allowed while repairs are being made unless appropriate measures have been taken to prevent corrosion and only then if the depth is not sufficient to weaken the metal. By close inspection, you can usually detect the presence of corrosion and take the necessary preventive measures. However, if you are in doubt as to whether or not the effects of corrosion have weakened a part, reject it.

1-21. Now that we have discussed the general rules for inspection of a fabricated or repaired part or structure, let us consider the inspection of these same areas to insure compliance with drawings and specifications.

1-22. **Comparison of the Inspected Items with Drawings and Specifications.** Any time a drawing or specification is received, the information contained has been incorporated into the drawing for a specific purpose. Normally, it is not our option to change specifications. If they are not correct, the authority to change them lies with the originator of the specification, drawing, or blueprint.

1-23. In the previous volumes of this course, we have discussed drawings and specifications. In our discussion there, we explained the need for proper interpretation of symbols and the need for accuracy when transcribing the information contained in the prints and specifications. As a supervisor, it is your responsibility to insure that those measurements have been accurately interpreted and that the materials specified have been used during fabrication of both repairs and parts. You must ask yourself the following questions during your inspection of a part or repair fabricated, using information from a print or specification prior to approval of the completed job:

- Scale—Has proper interpretation been made of the scale signified?
- Material composition—Has the material specified been used?
- Heat-treatment—Has the material been properly heat-treated to the temper designation specified?

- **Tolerance**—Are the dimensions of the completed part within the tolerances specified?

If the answer to any of these questions is "No," and if the lack of compliance with the specifications may change the value of the item, it does not pass inspection. Finally, although it is not usually stated in specifications, poor quality of workmanship should be another of the basic reasons for turning down a fabricated product. Repairs are but one item to be inspected by an airframe repair supervisor. A safe shop is a must to protect both equipment and personnel.

2. Inspections and Evaluations Insuring Safe Airframe Repair Shop Operation

2-1. So far in this chapter, we have been discussing those inspection requirements which pertain to the actual repair job. There are however other inspections and evaluations dealing with your shop which insures that it is operating safely in accordance with approved procedures outlined in the controlling directives for the shop. Without these inspections and evaluations, a shop is apt to become inefficient, and as a result become prone to losses in production, unsafe working conditions, and a lack of good supply discipline.

2-2. The information in this section will help you to maintain high-level production and quality maintenance in conjunction with the shop mission and your assigned responsibilities. It will contribute to making your shop a safe place to work, to making your equipment safe to use, and to dependable stocking of available supplies in the proper quantities and locations. We will discuss inspection procedure, first, and work areas second.

2-3. **Inspection Procedures.** It is necessary for you to inspect the shop work areas to see that floors are clear of metal and other hazardous material, that equipment and tools are safe to use, and that combustible materials are properly stored. You must also inspect supplies to see that the supply levels have been maintained properly and that all supplies have been stored properly.

2-4. **Work Areas.** Work area inspections include the airframe repair shop, the Fiberglas shop and other areas which remain a part of your responsiblity. A shop inspection need not necessarily be conducted at any given time; however, you should inspect the shop daily, even while the work is being performed. The supervisor usually accomplishes the inspection; however, the working supervisors as well as the workers should be on the alert for discrepancies at all times. Let's next take a look at how work areas are inspected.

2-5. Shop inspections include inspecting for safety and preventive measures. Since there are so many inspection items, the following list will help you to remember some of the items to inspect:

- Cleanliness of floors and work benches.
- Rag storage.
- Acid storage.
- Flammable storage.
- Scrap metal storage.
- Fire extinguishers.
- Fire exits.

2-6. Each of these items deserves further discussion in the same order as listed, because of its importance to the fulfillment of the airframe repair specialist's mission.

2-7. *Cleanliness of floors and workbenches.* You should inspect all floors and workbenches for oil, grease, dirt, and scrap metal. Grease and oil on the floor may cause someone to slip and be injured. Check behind cutting machines for scrap metal. This condition is especially hazardous to workers when they are recovering cut pieces of metal.

2-8. *Rag storage.* Rags should have two storage containers, each equipped with a self-closing lid. One container should be clearly marked for CLEAN RAGS ONLY; the other, for OILY RAGS ONLY. As you continue with the inspection, you should make sure that the rags have not become mixed. You should also check to see that the oily rag container is emptied daily in order to eliminate a fire hazard.

2-9. *Acid storage.* Check the acid storage area to see that all containers are closed. The door of the acid storage area should be marked to warn persons that acid is stored inside. The storage area should be located away from machinery or other equipment that may be damaged by the acid fumes. It is also a good idea to have the acid storage area lined wiht lead, since lead resists acid corrosion better than most metals.

2-10. *Flammable storage.* Check the shop to insure that gasoline is not stored inside the building. Gasoline should be stored in an outside storage area and in a clearly marked container.

2-11. *Scrap metal storage.* Check the scrap metal storage area to insure that different types of metals are stored in properly marked containers and that no scrap metal is on the floor. Also, during your inspection, check for metal waste. Many times large pieces of metal that could be used to fabricate small items have been thrown away; therefore, a separate storage area should be designated for the larger and smaller pieces of metal.

2-12. *Fire extinguishers.* Fire extinguishers that are ready for use are important items in any shop, especially the airframe repair shop, since your shop is often exposed to hot sparks during metal fabrication procedures. Fire extinguishers should be checked often for proper location, seals, markings, and inspection tags. Also, the areas around the extinguishers should be clear. The fire extinguisher location should be marked with a target arrow or with diagonal red and white stripes visible from any direction within the shop. Fire extinguishers are checked each month by the fire department; however, during your inspection, check to see that the inspection tag has been properly signed by the fire department inspector and dated so that you can tell when the next inspection is due. Check the seals on your fire extinguishers; when one is found broken, send the extinguisher to the fire extinguisher shop for an inspection or for recharging.

2-13. *Fire exits.* All fire exits should be clearly marked and kept clear at all times. The supervisor has the responsibility for inspecting the shop to see that the exits are clear; however, everyone else is also responsible for seeing that these same exits are kept clear. All personnel in the shop should know where the exits are. A building evacuation plan should be so located within the shop that all personnel know the proper routes for evacuation.

2-14. As you can see, there are many things to look for when you are inspecting your shop other than just quality workmanship. It takes time to learn these things; however, this is no reason why you cannot make yourself an inspection checklist of all your required inspection items. This checklist should prove to be very useful and should insure that you do not overlook even the smallest item. After you gain experience, you will find yourself making inspections in the shop and on the job without even realizing it. Inspection of the shop area is but one of the inspections necessary within the shop. Next, we will discuss inspection of equipment within the shop.

3. Inspection of Equipment

3-1. Equipment with which we are here concerned is broken down into two categories: stationary and handtools. Equipment should be inspected by the supervisor to make sure that it is in good working condition and that it is safe for use. Stationary equipment is inspected monthly; however, handtools do not require a formal inspection that often, because restrictions on their use are not as critical.

3-2. **Stationary Equipment.** There are several inspection items for stationary equipment, such as those shown in figure 2. The first item is cleanliness. Check the paint for grease spots, dirt, and any other foreign substance. Check the unpainted area for rust and grimy oil or grease; be sure that the rolls are lightly oiled to prevent rust. Check your stationary equipment to see that only the authorized colors of paint are used: orange for extremely hazardous areas, ivory for less hazardous areas, and machine gray for any other painted area. The remaining items to be checked were discussed in Volume 2 of this course.

3-3. To refresh your memory a little, let's discuss an inspection of the *power slip roll forming machine* to see what is to be done. This machine is shown in figure 3. First, you make a visual check of the painted and unpainted surfaces. Next, check to see that ivory paint has been used to identify any hazardous work areas on the machine, such as the upper roll locking handle, the upper roll raising lever, and the moving parts at each end of the rolls. Check to see that orange paint has been used to identify the extremely hazardous areas of the lower roll adjustment chain gears on each end of the shaft. These areas are designated as extremely hazardous because of the movable open gears. Now check to see if the machine needs lubrication or has been overly lubricated. Check the condition of the rolls for such things as misuse, pits, and creases.

3-4. Most machines are hazardous, and this one is no exception. A warning sign should be posted near the machine to warn personnel of all operational dangers. Check to insure that this sign is present and current. Check the operating switch to see that it is working properly, and check the electrical cord for breaks or cuts that could expose the wiring. Check the belt guard to see that the supporting bolts are secure and the guard is properly positioned. Now, operate the machine to determine its present condition and to see if any maintenance is needed.

3-5. Our next example of an inspection is a *stationary unishear*, such as the one shown in figure 4. Again, we start with cleanliness of the machine, then check to insure that the hazardous work areas are properly identified. On this machine, the ivory markings are different from those on the power slip roll forming machine in that the throat and area around the cutting blades are painted ivory. Check the lubrication points or grease cups for lubrication. Check the cutting blades for proper clearance and condition. Note that this machine should have a warning sign to warn personnel that eye protection is required when operating the machine. Check the operating switch, electrical cord, and warning light to insure that they are in good condition. Now check the overall condition of the machine by operating it.

3-6. Let's inspect one more piece of stationary equipment for the different markings and service

Check List For Stationary Equipment										
EQUIPMENT	Cleanliness	Markings	Lubrication	Maintenance and Forms	Operating Condition	Blades, Leaves, Rolls, Punches, Dies, Wheels	Warning Signs	Cords and Switches	Eye Protection	Guards
Power Slip Roll Forming Machine	✓	✓	✓	✓	✓	✓	✓	✓	▨	✓
Manual Slip Roll Forming Machine	✓	✓	✓	✓	✓	✓	▨	▨	▨	✓
Power Squaring Shears	✓	✓	✓	✓	✓	✓	✓	✓	▨	✓
Manual Squaring Shears	✓	✓	✓	✓	✓	✓	✓	▨	▨	✓
Circle Shears	✓	✓	✓	✓	✓	✓	✓	▨	▨	✓
Power Ring and Circle Shears	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Unishears (Stationary)	✓	✓	✓	✓	✓	✓	✓	✓	✓	▨
Power Hacksaw	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Band Saws	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Drill Press	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rotary Punch	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Bar Folder	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Cornice Brake	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Box and Pan Brake	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Pittsburg Lock Forming Machine	✓	✓	✓	✓	✓	✓	✓	✓	▨	✓
Rotary Machines	✓	✓	✓	✓	✓	✓	▨	▨	▨	▨
Grinders (Stationary)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

✓ Inspection items.

▨ Items not required.

53450-5-1-2

Figuure 2. Checklist for stationary equipment.

requirements. For example, inspect a *bench grinder* of the type shown in figure 5. Here again, there are several items and areas to be checked. First, check the machine for cleanliness and proper identification of any hazardous areas. The wheel guard, face guard, and work rest are painted ivory to identify them as hazardous work areas. (The top of the work rest is not painted.) Most bench grinders have permanently lubricated bearings; but since some do not, you will need to check your particular machine for lubrication. Pay particular attention to the grinding wheels, making sure to check each grinding wheel for cracks, chips, wear, and loose mounting nuts. Check to see that this machine has a warning sign indicating that eyes must be protected when one is operating the machine. Make sure that a pair of goggles or a face shield is located near the machine and that each is in good condition. Check the operating switch and electrical cord for proper operation and serviceability. Next we come to the guards and work rest. Check to insure that the grinding wheel guards cover two-thirds of the grinding wheels. Also check to see that the work rest is adjusted so that it does not touch the grinding wheels and that there is no more than a ⅛-inch clearance between the work rest and the grinding wheels. Now, operate the machine and check for any vibration which could indicate loose mounting bolts, worn bearings or shaft, or a bent shaft.

3-7. **Handtools.** Inspection of handtools involves checking the condition and serviceability of those toolkit items charged to an individual. A monthly or quarterly inspection is usually sufficient; however, it is your responsibility to keep

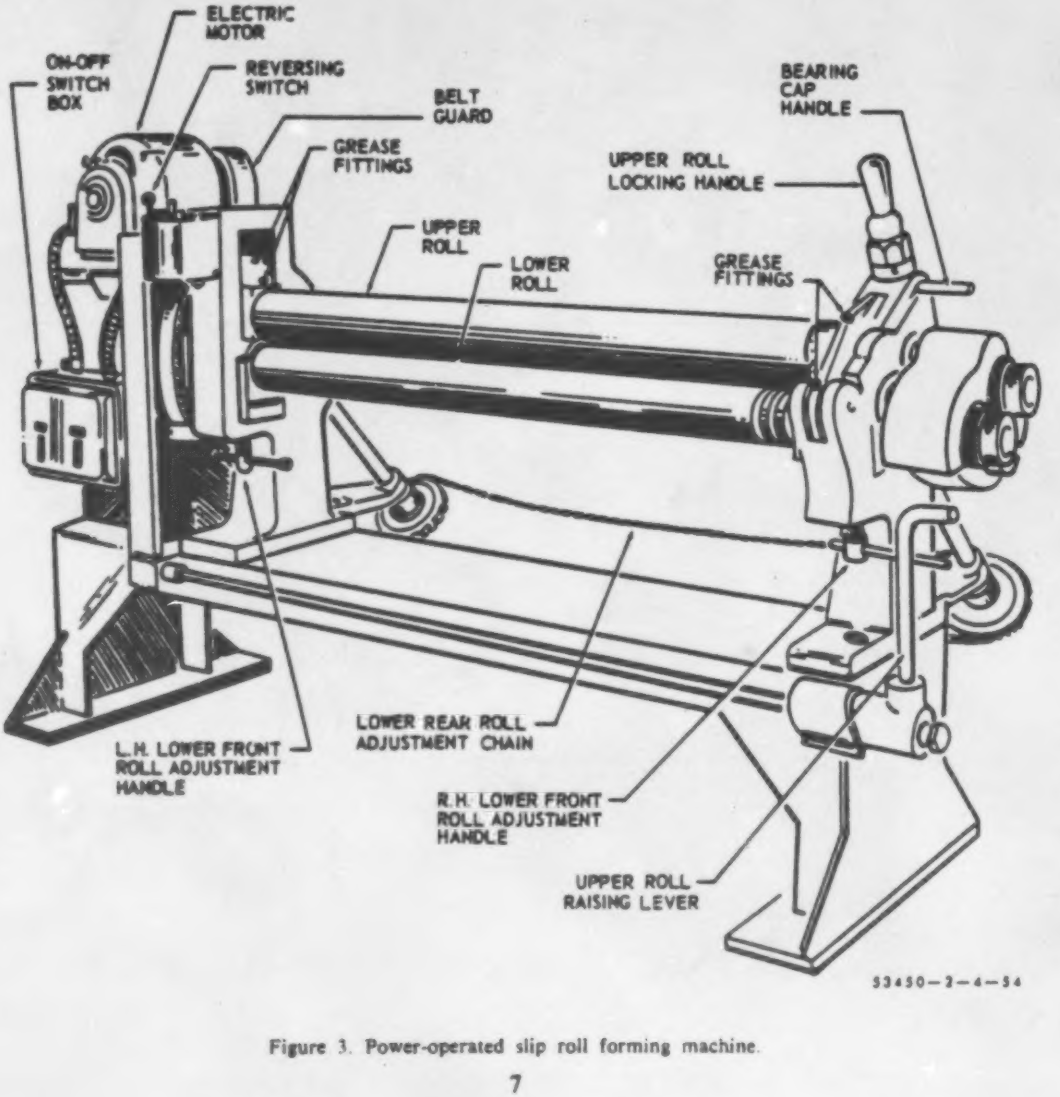

ELECTRIC MOTOR
ON-OFF SWITCH BOX
REVERSING SWITCH
BELT GUARD
GREASE FITTINGS
UPPER ROLL
LOWER ROLL
BEARING CAP HANDLE
UPPER ROLL LOCKING HANDLE
GREASE FITTINGS
LOWER REAR ROLL ADJUSTMENT CHAIN
L.H. LOWER FRONT ROLL ADJUSTMENT HANDLE
R.H. LOWER FRONT ROLL ADJUSTMENT HANDLE
UPPER ROLL RAISING LEVER
53450-2-4-54

Figure 3. Power-operated slip roll forming machine.

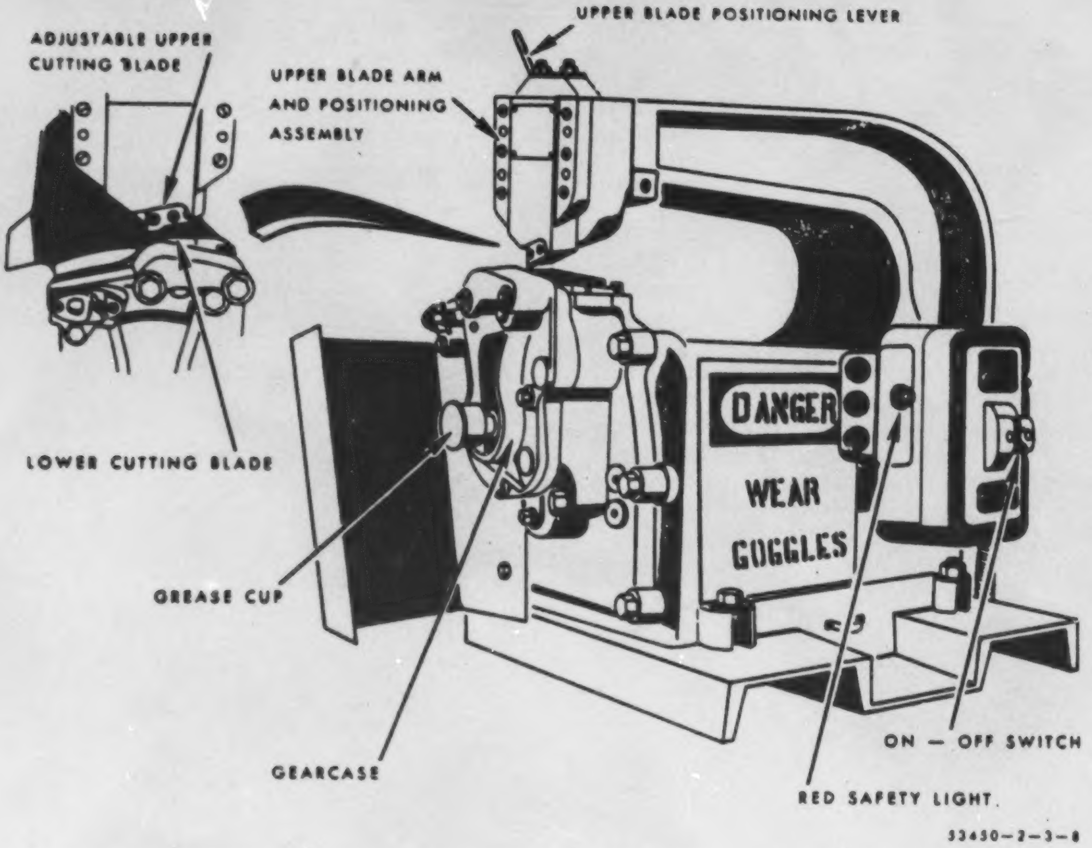

UPPER BLADE POSITIONING LEVER
ADJUSTABLE UPPER CUTTING BLADE
UPPER BLADE ARM AND POSITIONING ASSEMBLY
DANGER
WEAR GOGGLES
LOWER CUTTING BLADE
GREASE CUP
GEARCASE
ON — OFF SWITCH
RED SAFETY LIGHT
53450-2-3-8

Figure 4. Stationary unishear.

all tools assigned to you in good working condition. Many of the tool checks are the same as those which we have studied earlier in this course.

3-8. Inspect *hand snips*, or *shears*, for dull cutting blades, loose hinge bolts, damaged blades, and corrosion. These conditions usually result from misuse. Check *hammers* and *mallets* for broken handles and loose wedges; also check for rough faces on the hammerheads. *Chisels* are checked for mushroomed striking heads, dull cutting edges, and soft cutting edges. *Center* and *prick* punches are inspected for dull points, point angles, soft points, and mushroomed striking heads. Inspect *rivet* sets for mushroomed striking heads. Finally, check all *screwdriver* blades and handles for cracks and breaks. No inspection by a supervisor would be complete, until personnel were included.

4. Inspection of Personnel

4-1. Inspection of personnel in the airframe repair shop, which we will now discuss, is somewhat different from other types of personnel inspections, in that, you are looking for conditions that may result in injuries to personnel, such as the wearing of jewelry and loose clothing when they are operating machinery.

4-2. You should be observant at all times for the practical joker in the shop. He is the one who thinks that anything he does is humorous and that any prank he commits is all right no matter how it affects someone else. In an airframe shop this situation cannot be tolerated, because such a person will eventually hurt either himself or someone else—or both.

4-3. The practical joker is not the only person you should observe when making an inspection. What about the man who is operating a grinder without eye protection or guards, or the worker who is using the side of a grinding wheel? Either of these persons may not hurt as many people as the practical joker, but he can surely hurt himself. Again, what about the man who wears loose clothing when he is operating a power slip roll, or the one who wears a ring or a loose identification bracelet when working on or operating machinery? Such loose clothing, such a ring, or such a bracelet might be caught by the machine, with the possibility that a finger, hand, or arm might be pulled into the cutting blades or other moving parts. Last we shall discuss the inspection of adequate supplies, without which, an airframe repair shop could not operate.

5. Inspection of Supplies

5-1. **Supplies** such as materials for your work center, work orders, bench stock, and one-time orders should be kept separate and under control. Some of the supplies must be stored in a particular manner and in a designated storage area. For example, gasoline and other flammables must be stored in safe, well-ventilated areas and approved containers. Other supplies are stored in bins that are marked to identify the contents. Now let's see how you inspect supplies.

5-2. **Use and Control of Supplies.** Make sure that supplies are kept separate and that they are used as intended. For instance, work order materials should be kept separate from your bench stock and one-time issue supplies. By marking all work order materials with the specifically applicable work order numbers for which they are intended, you can be sure to identify the material issued with the correct job.

5-3. One method of controlling supplies is to screen the DD Form 1150, Request for Issue Turn-In. The inspection for one-time issue includes the screening for items that could be substituted from bench stock. Using this form, you will check the quantity requested in order to prevent the overordering of items. For instance, if the request is for two boxes of any particular item and only one box is actually needed, the quantity should be reduced. Why? Because it is not good practice to order more supplies than you need just to have them on hand. In other words, when you inspect the use and control of supplies, you are actually inspecting to see that good management procedures are being followed.

5-4. **Storage of Supplies.** You have probably noticed that bins usually consist of boxes sitting on shelves in the bench stock storage area. Each box is identified with a tag, which includes the item's description, stock number, and document number. The last four digits of the document number are the location numbers for the box (bin). Likewise, each item has a stock number, and that item is supposed to be stored in the bin that lists that stock number. Knowing these

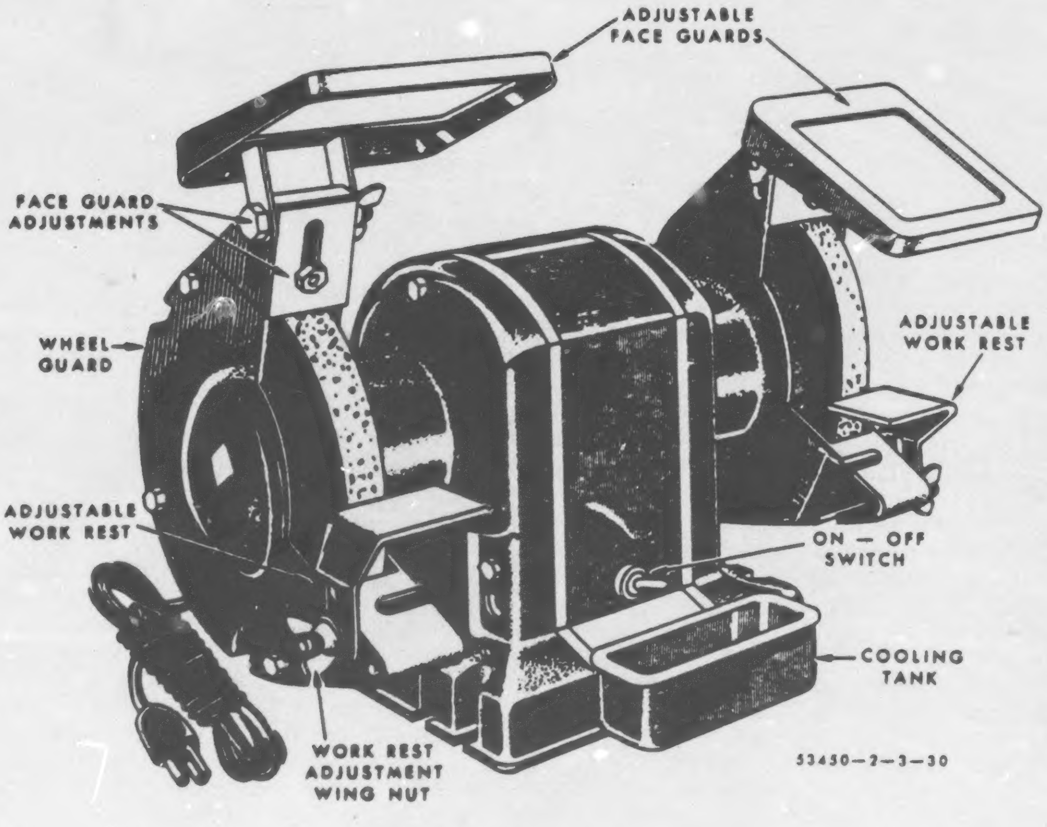


Figure 5. Bench grinder.

things, you should make sure that items are properly labled and stored—each in its designated location. Items should not, therefore, be mixed. For instance, you do not want ¼-inch steel rivets mixed with ¼-inch aluminum rivets.

5-5. Accordingly, during your inspection of bench stock items, check to see that the item description fits the item stored in the box and that the box is stored in the proper location. Also, check for items that have been exhausted so that an *out-of-cycle issue* can be requested.

5-6. Sheet stocks of metals, such as galvanized steel, stainless steel, and aluminum, are usually stored in an upright position. The surface of metal sheets, such as stainless steel, magnesium, and aluminum, must be protected to prevent scratches. This last is usually done by placing cardboard between the sheets *(interleaving)*. As you remember, you learned of this procedure in an earlier volume of this CDC when you studied about the care of metals. As with other bench stock item storage, the bins should be clearly marked to identify the metals, and each bin should exhibit the stock number of the material it contains. If the metal is on bench stock, it should have a document number on the tag.

5-7. This completes our discussion of inspections of work areas, equipment, personnel and supply. But, you say, can you tell me why inspections are performed, or what to do if I find something wrong during an inspection? These questions are answered next.

6. Interpretation and Correction of Inspection Findings

6-1. We should point out that you usually inspect and interpret the findings at the same time. However, to make the text easier to understand, we have separated the two topics. Also, although corrective action follows the interpretation of inspection findings, because the two are so intrinsically interrelated, we will discuss them under one heading. Bearing this interrelationship in mind, let's explore some examples of interpretation of inspection findings as well as the corrective actions taken.

6-2. **Work Areas.** Suppose that during an inspection you find oily rags mixed with clean rags. You have learned from our previous discussion that oily rags should not be stored with clean rags and that separately marked containers with lids should be used. Recalling this, you know that in this situation there is a violation of safety directives which must be corrected.

6-3. You must, however, interpret the inspection findings before you can initiate any corrective action. For instance, think about the containers for the rags. In the first place, are these containers properly marked? If they are not, the discrepancy is not necessarily due to carelessness or neglect. On the other hand, if the containers are properly marked, then you could consider the violation of mixing oily rags with clean rags the result of carelessness.

6-4. Now let's think about what you can do if the containers *are* clearly marked. Obviously, you can caution all of the workmen to make sure that they use the proper storage for oily and clean rags. After doing this by instituting followup inspections and by close observation of the containers, you should be able to spot the offender and, by dealing directly with him, to prevent recurrence of the violation.

6-5. Now let's look at the other side of the situation. Suppose that the containers are *not* properly marked. This means that you, as the supervisor, are at fault as much as the person who put the oily rags in the container with the clean rags. You can correct the violation by marking the containers properly and instructing the workers in the use of storage containers.

6-6. **Equipment.** Equipment inspection can reveal many discrepancies, since there are many items to inspect. Suppose that during the inspection of a bench grinder, you find one of the wheels with a small crack. This situation will require that you decide whether the wheel can be *dressed out* or it should be replaced. If, by a closer examination, you discover that the length of the crack is from the grinding face of the wheel to the arbor hole for the shaft, it cannot be dressed out. Such an action would create a hazardous condition for the machine operators; therefore, your decision (recommendation) should be to replace the defective wheel with a new one.

6-7. Now suppose further that you have evaluated the findings and made a recommendation to correct the discrepancy by the installation of a new wheel. A spare wheel should be available in the shop; however, if one is not available, order a replacement. In fact, it is advisable for you to order two wheels, so that one will be available for standby.

6-8. But now suppose that a replacement wheel is not available; if this is the situation, you should not use the grinder. Instead, with the power supply turned off, remove the old wheel and place a sign on the grinder prohibiting operators from using it. Why shouldn't the grinder be operated with only one wheel? The answer is that the machine will be out of balance and will therefore vibrate. This is the real reason why it is a good idea to have a spare wheel on hand; with such a wheel, the grinder will not have to be put out of operation while a new wheel is being obtained.

6-9. Let's look at another example. Suppose that a ¼-inch portable electric hand drill does not operate. Your evaluation of the trouble indicates that the motor is burned out and that the gears are worn. As a result of your evaluation, the drill should be condemned. To confirm this, you should have the electric shop check the motor, the switch, and the power cord. After this has been done, the gears should be checked to see whether or not they are worn or have broken teeth. Suppose that your evaluation is proved correct, that the drill motor is burned out and the gears are defective. Since the cost to repair the drill is excessive, a replacement should be made. First, see that the condemned drill is tagged with a status tag. Initiate the tag by filling in the necessary information. The tag should then be atached to the defective drill and signed by a supply inspector authorized to sign tags. Next, as the supervisor, you should initiate an AF Form 601b to turn in the condemned drill and request a replacement.

6-10. **Supplies.** Suppose, again, that the inspection of supplies reveals that bench stock and work order materials have been mixed. You should evaluate the discrepancy and determine the cause before making any recommendation to base supply. To do this, let's use the information you learned earlier in the text. Remember that bench stock and work order materials should be kept separated.

6-11. First of all, determine whether or not there is proper storage for work order and bench stock materials. Next, determine whether the work order materials have been properly marked and whether the bench stock storage bins have been properly marked. Having done these things, you should find out whether or not all personnel are properly trained in the procedures for storing supplies in the shop.

6-12. If you find that a discrepancy is due to inadequate storage, you can correct it by making specific separate locations for work order and bench stock materials. If you discover that the cause is due to personnel not knowing the procedures for storing supplies, you should initiate a training program to instruct all personnel in proper storage procedures.

6-13. In the next chapter, the need for rigid inspections both in the shop and on the job should become obvious to you as we discuss optic alignment. Why? Because the tools necessary to perform optical inspections must be kept in good condition constantly or proper optical inspection cannot be performed.

CHAPTER 2

Optical Alignment

IN THE FABRICATION and maintenance of aircraft, proper alignment is essential to safe, economical, and reliable operation. An aircraft out of alignment is unsafe. Yet aircraft are subjected to many varied and intense stresses and are, therefore, likely to get out of alignment. Because high speeds and altitudes increase hazards due to misalignment, alignment checks of aircraft increase in number and frequency with increase in speed and performance.

2. Routine alignment checks are made during manufacture and maintenance of aircraft in accordance with alignment specifications. In addition, checks are necessary when sudden, excessive stresses have been applied to the aircraft. Misalignment may be detected by observation of a change in flight characteristics reported by the pilot or crew; or by the detection of popped or pulled rivets, of a buckled or cracked skin, of wear on tires, or of damaged landing gear. All of these defects may result from hard landings, overload conditions, flight in turbulent air, excessive speeds, acrobats, and/or after replacement of components or repairs to major structural members.

3. Optical equipment is generally accepted by industry and the Air Force as the latest and most accurate method for the testing, alignment, and inspection of airframe structural members. For this reason, optical alignment checks used to determine whether or not all structural members are in correct relationship with each other are discussed in this chapter. The procedures involved consist of leveling the aircraft by jacking, establishing vertical and/or horizontal optical reference planes, and measuring angular deviation (or displacement) from these planes. NOTE: *Alignment checks must be made in still air, and the aircraft must be on reasonably level, hard-surfaced floors.*

4. All optic instruments are made up of one or more optical elements which are combined to produce the desired effect. The most common optical elements used are mirrors, prisms, and lenses. To understand optical instruments better, we will study the nature of light, what these optical elements do to rays of light, and the setup and adjustment of the various instruments used in the alignment of aircraft.

7. Fundamentals of Optics

7-1. The exact nature of light is not definitely known. However, it is generally accepted that light is a form of energy which radiates from luminous objects and seems to travel in waves. When these light waves reach the retina of our eyes, we are able to see the luminous objects or reflecting objects. In this section we will discuss terms used in optics, the reflecting and refracting characteristics of light, the effect of a lens on light rays, and the focal plane as pertains to optics.

7-2. A luminous object is one that produces light waves; it shines by its own light. The sun, a lamp, or glowing, white-hot metal are examples of luminous objects. Nonluminous objects do not produce light themselves. We see them only because they reflect light from other sources. The moon is an example of a nonluminous object. We see it only because it reflects light which originally comes from the sun. Most things that we see are nonluminous objects which reflect light from other sources.

7-3. Some of the terms we use when speaking of light rays in the following paragraphs are:

a. A *ray of light* is the path traced by any point on an advancing light wave.

b. A *bundle of rays* consists of a group of rays coming from a common point.

c. A *beam of light* is a group of bundles of rays put together; a flashlight is a common example.

d. A *medium* is any form of matter with which light waves may come in contact. The air, water, and glass are examples of such media.

(1) A *transparent medium* is one through which objects can be seen clearly and distinctly, such as a window pane.

(2) A *translucent medium* is one through which light will pass, but the light is so spread throughout the medium that objects behind it

cannot be clearly and distinctly seen. A common example of a translucent medium is frosted glass.

(3) An *opaque medium* is one through which light cannot pass, such as a stone wall for instance.

7-4. **Light Reflection and Refraction.** Certain things happen to light rays when, while traveling through one medium, they strike another medium. If a light ray strikes a new medium and is sent back into the medium through which it came, it is said to be *reflected*. If the ray passes into a new medium and changes its course, it is said to be *refracted*.

7-5. In optical alignment we are concerned with two kinds of reflection: regular and irregular. *Regular reflection* occurs when a beam of light strikes a smooth surface, such as a flat and highly polished piece of metal, a mirror, or the surface of still water. The beam of light involved is reflected regularly and takes a definite course. regular reflection can be compared to the bouncing of a perfectly spherical rubber ball on a smooth polished floor. If such a ball is dropped straight down, it will bounce back up along its original path. If it is thrown on the floor at an angle, it will bounce back up at the same angle in the *opposite direction*.

7-6. When the beam of light is reflected from a rough surface—such as a piece of paper, unpolished metal, or powdered glass—the result is an *irregular reflection*. The light involved would be scattered in all directions. Irregular reflection is comparable to bouncing a perfectly spherical rubber ball off a pile of rocks instead of a smoothly polished floor. Such a ball would rebound in any direction, depending upon where and how it hits.

7-7. Reflected light rays obey the following laws of reflection, whether they strike a smooth or a rough surface (see fig. 6):

- The *incident ray*, the *normal*, and the *reflected ray* are all in the same plane.
- The *angles of incidence* and the *angles of reflection* are equal.

7-8. The most commonly known type of surface used for regular reflection is the mirror. When a person looks into a mirror, he sees a reversed image of himself which appears to be behind the mirror. To the observer's eye, the image of the object appears to be behind the mirror, because this is the direction from which the light rays are coming after they have been reflected. Also, the image appears to be at a distance behind the mirror, equal to the distance of the object from the front of the mirror.

7-9. When light passes from one medium into another medium, its rays are bent or refracted. Let us use a familiar analogy to illustrate this process. Suppose that a column of airmen is marching eight abreast across a hard, dry drill field when suddenly it encounters a diagonal strip of sand. Naturally, airmen cannot march as fast in the sand as they can on the hard, dry ground. Hence, when the first airmen in the column reach the sand, they slow up, while the other airmen continue to march at their normal step. The other airmen finally slow up when they reach the sand; but, before all the men reach the sand, the column is given a command, changing direction. The effect is a bend in the line of the march.

7-10. The same thing occurs to a beam of light when it enters a new medium of different *density*. Light travels more slowly in water, glass, or other transparent media than it does in the air. Light is also bent when it travels from the air into one of these media or from one of these media into the air. The direction in which the light is bent depends upon the density of the medium into which it passes. For example, when light passes from air into a dense medium, such as water, it is refracted toward the normal (perpendicular). On the other hand, when light passes from water into air, it is refracted away from the normal, as illustrated in figure 7.

7-11. Of course, if the light enters the water on a path that is perpendicular to the surface of the water—in other words, along the normal—it is not refracted but continues is the same direction. (See fig. 7.)

7-12. Refraction can be used to change the direction of light. This change is brought about by changing the position of the glass or the shape of the glass. If a ray of light passes obliquely through a plate of glass with parallel surfaces, it will emerge in a direction parallel to the direction it entered. This is true because a ray of

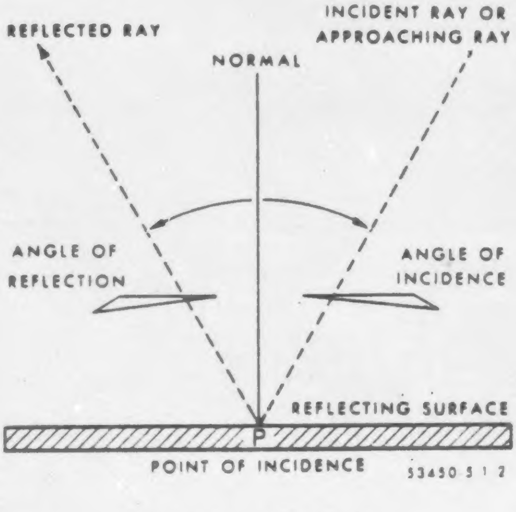


Figure 6. Laws of reflection.

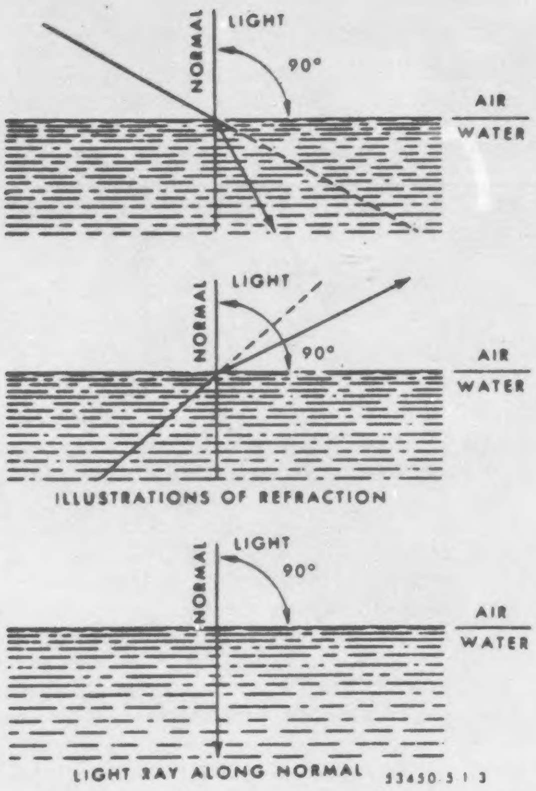


Figure 7. Light ray refraction.

light entering a piece of glass will be refracted a certain amount toward the perpendicular. When the light ray leaves the glass, it is refracted by that same amount toward the perpendicular. When the light ray leaves the glass, it is refracted by that same amount away from the perpendicular, as illustrated in figure 8.

7-13. Light rays entering a body of glass are refracted toward the thick part of the glass. Therefore, curved glass will either converge or spread light which passes through it. Figure 9 illustrates how irregular-shaped glass will change the direction of the light.

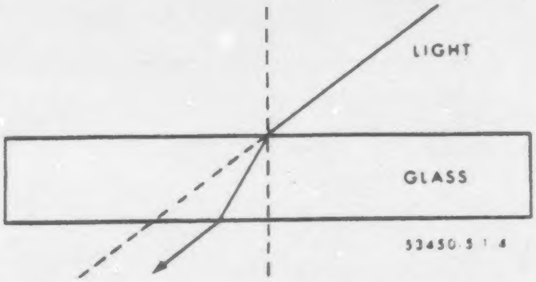


Figure 8. Refraction in plate glass.

7-14. **Prisms.** In optical instruments, it is often necessary either to change the direction or to shift the position of the light rays. This is accomplished by using bodies of glass known as *prisms.* (See fig. 10.) Light entering a prism may be either reflected or refracted. The angle at which the light enters the prism determines whether reflections or refraction will take place. The critical angle is the transition point between reflection and refraction, as shown in figure 11. If light rays enter a prism *at* the critical angle, they are reflected and refracted. If light rays enter the prism *within* the critical angle, they are refracted through the prism. If they strike the prism *beyond* the critical angle, they are reflected out of the prism.

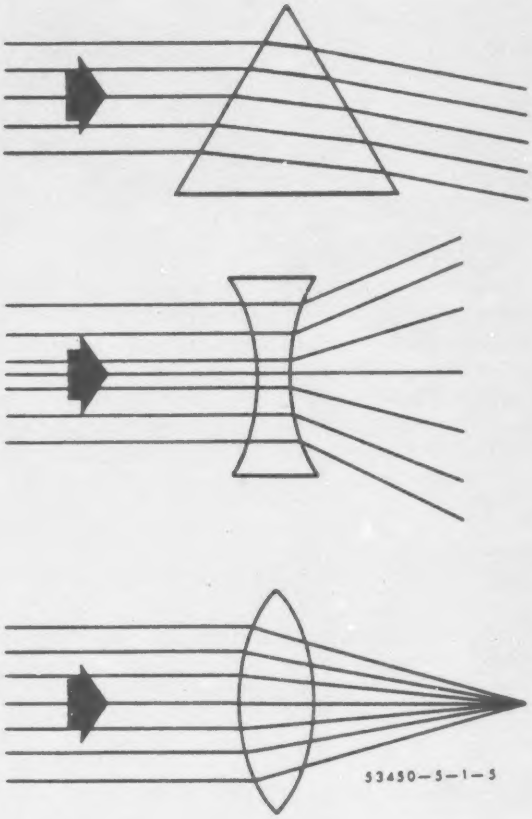


Figure 9. Effects of different shapes of glass.

7-15. A *pentaprism* is a five-sided prism which is used to change the direction of light rays 90° from their original path. The image comes out of the pentaprism in the position that it entered. Reflecting surfaces of the pentaprism are coated with a reflecting agent so that rays which strike the surface within the critical angle will be reflected out of the prism.

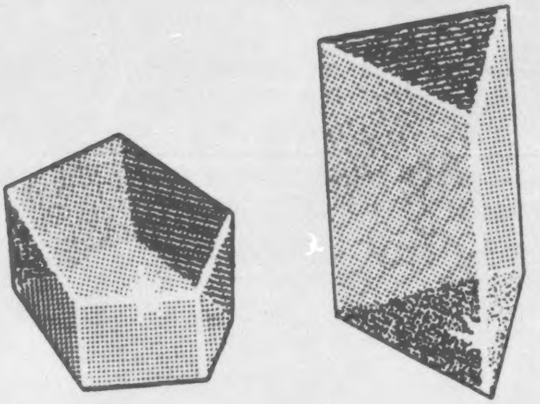
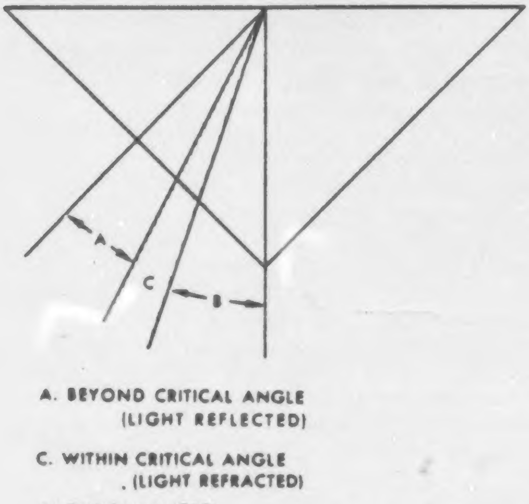


Figure 10. Glass prisms.

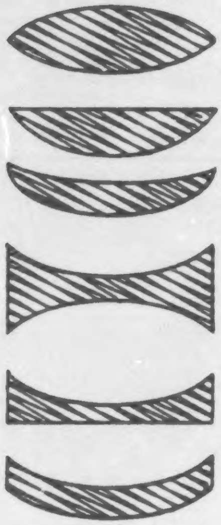
7-16. **Lenses.** A *lens* may be thought of as a group of prisms fitted together. It is a piece of transparent refracting substance whose opposite surfaces may both be curved or one of which may be curved and the other one flat, as shown in figure 12.

7-17. All lenses refract light. Some bring light rays to a point; others spread the rays. The shape of the lens determines whether light rays striking the surface will be converged or spread out. For example, the *convex* lens may cause a large number of light rays to converge due to the refraction of the rays toward the thick part of the lens. But regardless of the type of prism or lens used, the light rays are always refracted toward the thickest part.


A
C
B
A. BEYOND CRITICAL ANGLE (LIGHT REFLECTED)
C. WITHIN CRITICAL ANGLE . (LIGHT REFRACTED)
B. CRITICAL ANGLE

53450—5—1—7

Figure 11. Critical angle of prism.



53450—5—1—8

Figure 12. Lenses.

7-18. **Focal Plane.** The *focal plane* is a plane at which light rays passing through a lens may come together and form the image of an object, as shown in figure 13. The location of the focal plane depends upon the location of the object. As the object moves further away from the lens, the focal plane moves closer to the lens.

7-19. The focal plane of a camera is the film. The lens can be moved forward to adjust the focal length (distance between lens and focal plane) as the object moves closer to the lens. The lens system of the camera must be properly focused to obtain a clear picture. The camera raises the convex lens to converge light rays and form an inverted image of the object. The objective lens of a telescope works in the same way. A lens in the telescope must be moved backward and forward to bring the image of an object into focus, as we will cover in the following

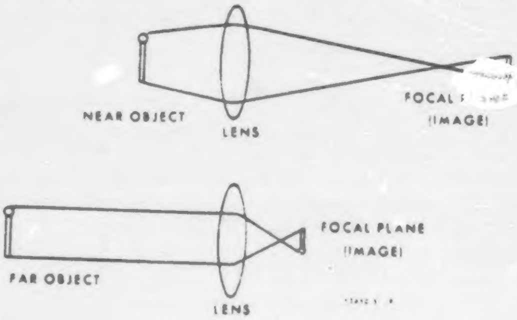


Figure 13. Examples of focal planes.

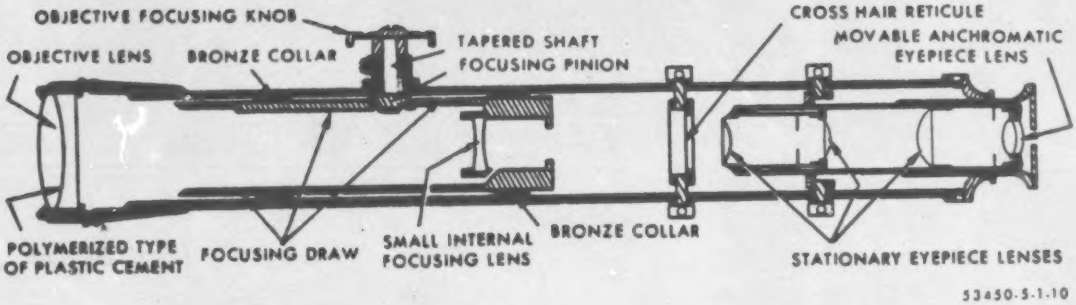

OBJECTIVE FOCUSING KNOB
OBJECTIVE LENS
BRONZE COLLAR
TAPERED SHAFT
FOCUSING PINION
CROSS HAIR RETICULE
MOVABLE ANCHROMATIC EYEPIECE LENS
POLYMERIZED TYPE OF PLASTIC CEMENT
FOCUSING DRAW
SMALL INTERNAL FOCUSING LENS
BRONZE COLLAR
STATIONARY EYEPIECE LENSES
53450-5-1-10

Figure 14. Cross-sectional view, internal focusing telescope.

section along with other information you need to understand telescopes.

8. Telescopes

8-1. One of the basic units used for the alignment of aircraft and jig construction is the *telescope*, as shown in figure 14. The tilting level and surveyor's transit employ its use. We will discuss their features, types, and pointing accuracy.

8-2. **Features and Nomenclature of Telescopes.** You can gain a better understanding of optical instruments by studying the basic features and nomenclature of the telescope, as well as the types of telescopes commonly in use. The features, nomenclature, and the types are given next.

8-3. *Objective lens.* Rays of light coming from an object within the field of view of the telescope are caught by the *objective lens*. These rays add up to form an inverted image of the object on the focal plane.

8-4. *Focusing lens.* The *focusing lens* is used to bring the light rays into focus by forming an image of the object on the plane of the crosshairs. Adjustment of the focusing lens is made by rotating the focusing knob as necessary. The focusing lens is located in a draw tube (cylinder), which is moved forward and backward inside the barrel of the telescope by means of a gear arrangement attached to the focusing knob. This is known as an *internal focusing system*. When the focusing lens is properly adjusted, the image on the plane of the crosshair is small and always inverted.

8-5. *Crosshair reticle (ring).* The *crosshair reticle* may be compared to a motion picture screen upon which an image is projected. This screen (plane) is a glass or plastic disc containing lines which locate the exact center of the plane.

8-6. *Eyepiece lens unit.* The telescope contains an *eyepiece lens unit* to make the image larger and more easily seen. In some telescopes, the eyepiece lens unit is designed to make the image appear in a normal right-side-up position, as shown in B of figure 15, while other telescopes have eyepieces which leave the image inverted, as shown in A of figure 15.

8-7. *Mechanical and optical axes.* Two other important parts of most telescopes are their *mechanical* and *optical axes*. The mechanical axis of a telescope is an imaginary straight line which passes through the center of the telescope barrel. The optical axis is an imaginary straight line

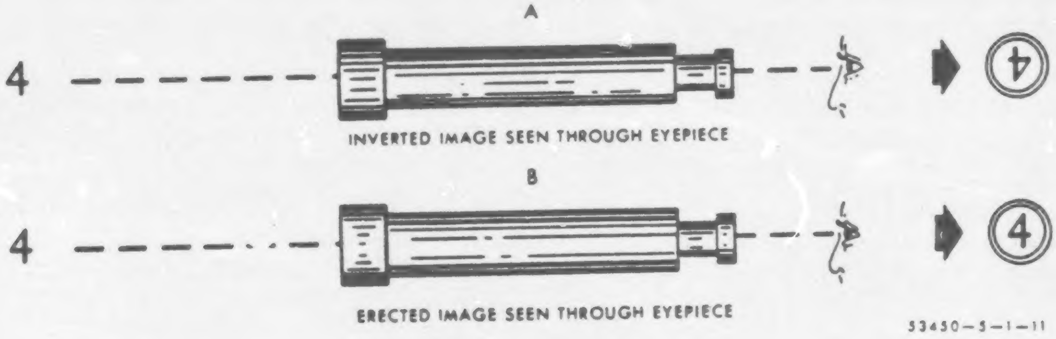

A
4
INVERTED IMAGE SEEN THROUGH EYEPIECE
B
4
4
ERECTED IMAGE SEEN THROUGH EYEPIECE
53450—5—1—11

Figure 15. Inverted and erect images.

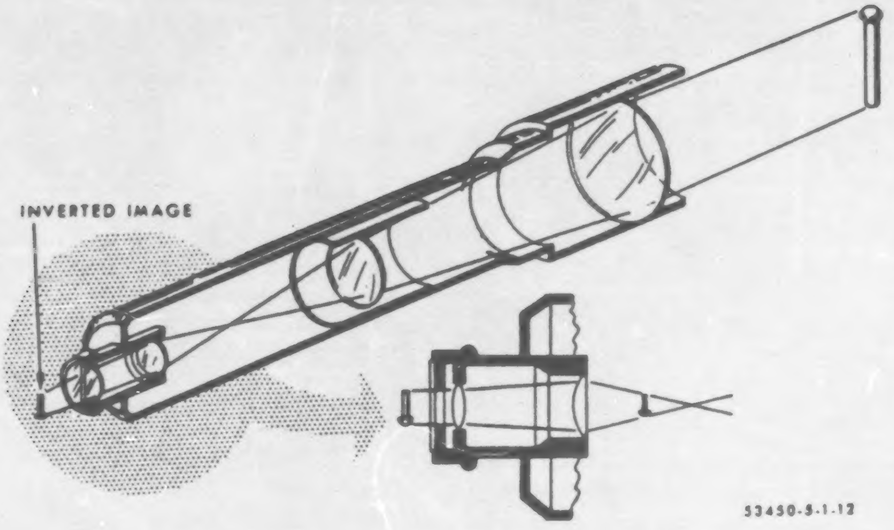


Figure 16. Celestial telescope.

which passes through the center of the lenses of the telescope. The center of the crosshairs will lie on the optical axis when the telescope is properly adjusted.

8-8. **Types of Telescopes.** A telescope whose eyepiece leaves the image inverted is known as a *celestial telescope;* this is the type generally used by astronomers, as shown in figure 16. An inverted image, as seen by the celestial telescope, is one which is upside down and on which the right side of the object appears on the left. An inverted image is illustrated in A of figure 15.

8-9. A telescope designed to erect the image of an object is called a *terrestrial* (land) *telescope,* as shown in figure 17. An *erect image* is one in which the image is in the same position as the object being viewed, with the top side up and the right side on the right. This is illustrated in B of figure 15.

9. Principles of Operation of the Telescope

9-1. Much could be said about the principles of operation of the telescope. We will, however, restrict our discussion to just these principles which seem particularly applicable to the airframe repair specialist.

9-2. **Parallax.** The focusing lens inside the telescope forms an image of the object being sighted. This formed image should be in the same plane as the crosshairs. If the image is not in the same plane as the crosshairs, the crosshairs

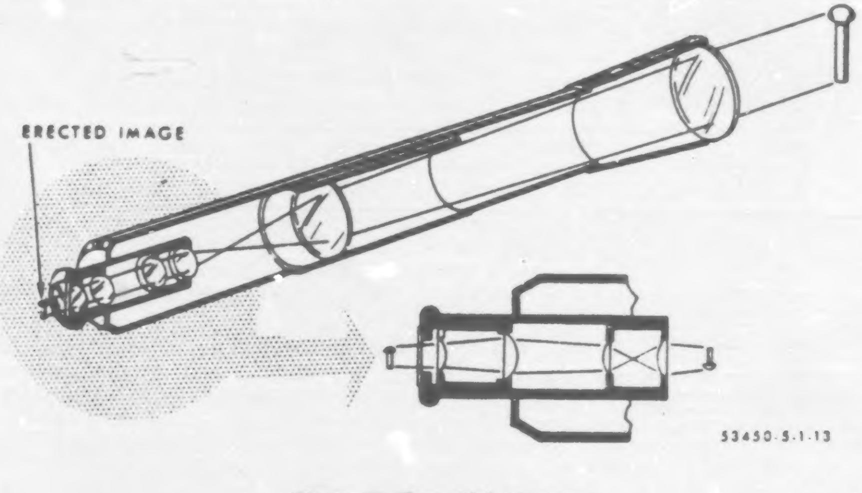


Figure 17. Terrestrial telescope.

will appear to move across the image when the eye is moved. This is known as *parallax*, as illustrated in example A of figure 18.

9-3. Whenever a reading is taken which involves adjustment of focusing, parallax must be checked for and eliminated. Parallax may be eliminated by adjusting the eye piece and objective focusing knob until the crosshairs and image appear to give the same results when viewed from any position of the eye, as shown in example B of figure 18.

9-4. **Magnification.** The rated power of a telescope (such as 28X, 30X, 42X, etc.) is the greatest *magnification* that can be obtained. This magnification occurs only when the telescope is at its infinite focus.

9-5. **Resolving Power.** The *resolving power* of an instrument is the capacity of its lens system to show detail. The resolving power is determined by the instrument's capacity to render a clear and distinct image of narrow separations, such as those encountered on scale graduations. Resolving power is measured by the smallest angular distance between two points that can be distinguished as separate points.

9-6. **Definition.** *Definition* is a general term used to express the results obtained with a telescope. The better the definition, the better the image of an object can be seen through a telescope. The definition of a particular telescope can be effectively appraised, first by viewing an object through the telescope being checked then by viewing the same object through a telescope with which you are familiar, and finally, by comparing the images of the two.

9-7. **Pointing Accuracy.** *Pointing accuracy* is the accuracy at which a target can be adjusted into a line of sight. It is relative to magnification

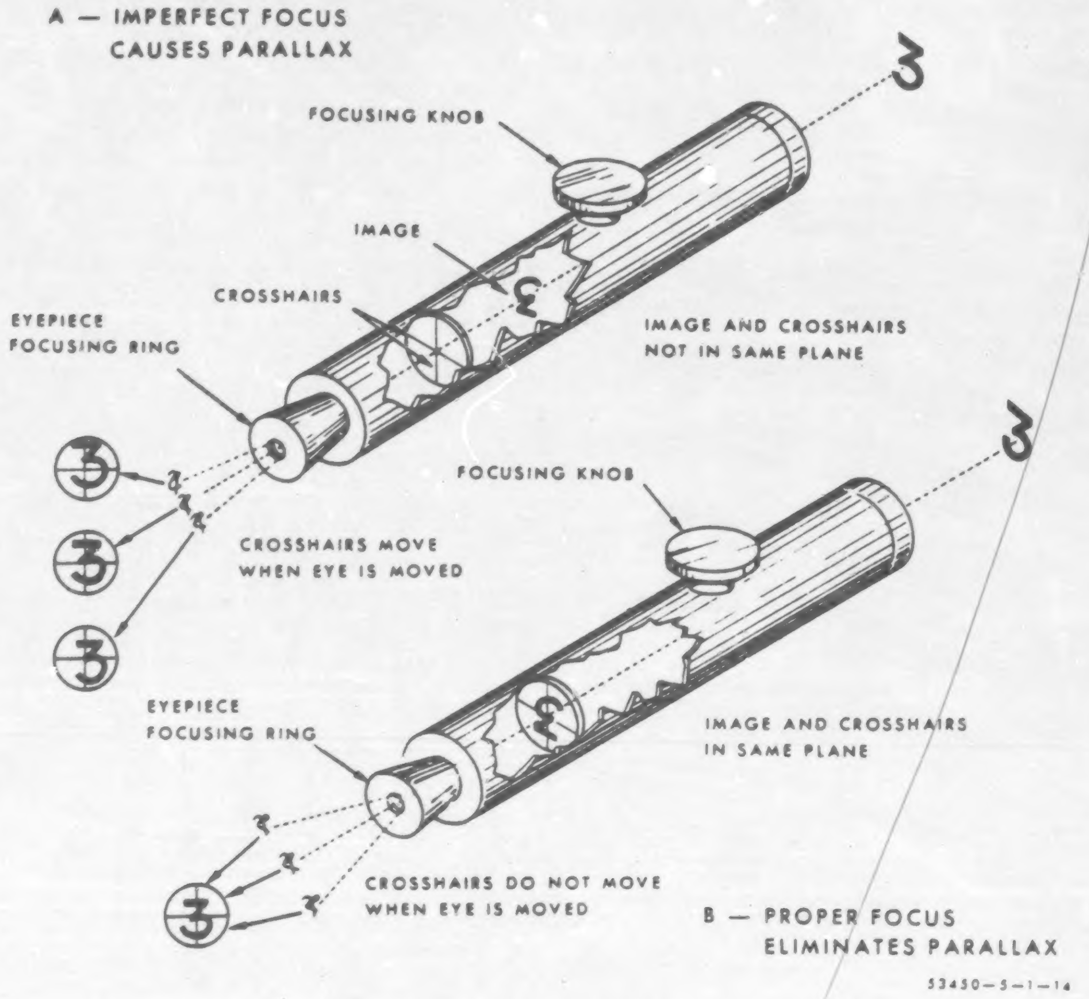

A — IMPERFECT FOCUS
CAUSES PARALLAX
FOCUSING KNOB
IMAGE
CROSSHAIRS
EYEPIECE
FOCUSING RING
IMAGE AND CROSSHAIRS
NOT IN SAME PLANE
CROSSHAIRS MOVE
WHEN EYE IS MOVED
FOCUSING KNOB
EYEPIECE
FOCUSING RING
IMAGE AND CROSSHAIRS
IN SAME PLANE
CROSSHAIRS DO NOT MOVE
WHEN EYE IS MOVED
B — PROPER FOCUS
ELIMINATES PARALLAX
53450-5-1-14

Figure 18. Parallax in a telescope.

but depends chiefly on definition. Crosshair arrangement and conformance of target or scale design will have a bearing on pointing accuracy. The accuracy with which a reading can be repeated from the same setting of the telescope and target determines the pointing accuracy of the instrument.

9-8. Remember that power alone does not classify the accuracy of a telescope. A combination of proper magnification, ultimate resolution, and clear definition are required for a good optical system. The two instruments we next discuss, first the sight level and secondly the transit, both employ the use of the telescope.

10. Sight Levels

10-1. The *sight level,* shown in figure 19, is an instrument which embodies the principles of optics. There are several types of sight levels, but the basic principle of each type is relatively the same as that of each of the other types. Each type consists of a telescope which can be set up so that its optical axis will rotate in a horizontal plane about the vertical axis of the instrument when the instrument is level. The term "sight level" is derived from the fact that sight levels have a telescope through which objects are sighted which distinguishes them from the machinist's level.

10-2. The term "line of sight," when associated with sight levels and other optical instruments, refers to the specific line of sight (essentially the path of a single ray of light) when the instrument is in a fixed position. This line of sight should not be confused with the horizontal and vertical planes that can be established by the sight levels and the transit, respectively. Since sight levels are used to establish a horizontal plane through 360° of arc, the horizontal plane is generated when the telescope of the sight level is rotated about its vertical axis. Now we will discuss the transit and its operation.

11. The Transit

11-1. The *transit,* shown in figure 20, is a basic instrument used extensively by construction engineers and surveyors. In their work, it is used in measuring horizontal and vertical angles and differences in elevations and distances, prolonging straight lines, spirit leveling, taking compass bearings, etc. We will discuss the parts of the transit, the geometry of the transit, and finally the procedures in setting up this instrument.

11-2. The use of transit is generally much less varied in the alignment of aircraft, where it is used to establish the vertical centerline of the fuselage and to measure angles, such as the attitude of the vertical fin and the sweepback angle of the wings. The transit may also be used for establishing horizontal lines of sight if a tilting level is not available.

11-3. A transit consists of a telescope mounted 90° to a horizontal axis which is supported by a trunnion framework. The entire framework, consisting of a base and two vertical standards, is mounted on a vertical axis. Thus, the instrument can be rotated about the vertical axis to sweep a vertical plane. This arrangement of the vertical and horizontal axis makes it possible to reverse the instrument and repeat a setting or *prove* a reading.

11-4. The term "transit the telescope" refers to the act of rotating the telescope about the horizontal axis. The term "rotate instrument" refers to the act of rotating the standards and telescope about the vertical axis. The term "reverse instrument" refers to rotating the telescope and standards 180° about the vertical axis and transiting the telescope 180° about the horizontal axis.

11-5. **Nomenclature.** Parts common to all transits and sight levels are the eyepiece focusing ring, the objective focusing knob, and the leveling screws. Figure 20 illustrates these and other parts of a transit. You should study the nomenclature carefully and become thoroughly familiar with each functional part of the transit.

11-6. *Eyepiece focusing ring.* The purpose of the focusing ring is to compensate for variations in eyesight of different observers, enabling each observer to bring the crosshairs of the instrument into focus.

11-7. *Objective focusing knob.* This focusing knob is used to bring the image of the target into focus on the plane of the crosshairs as observed through the eyepiece. It is rotated to compensate for variations in distance between the telescope and the various targets observed.

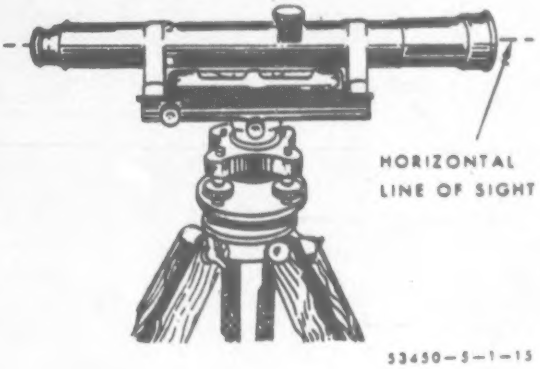


Figure 19. Sight level.

566

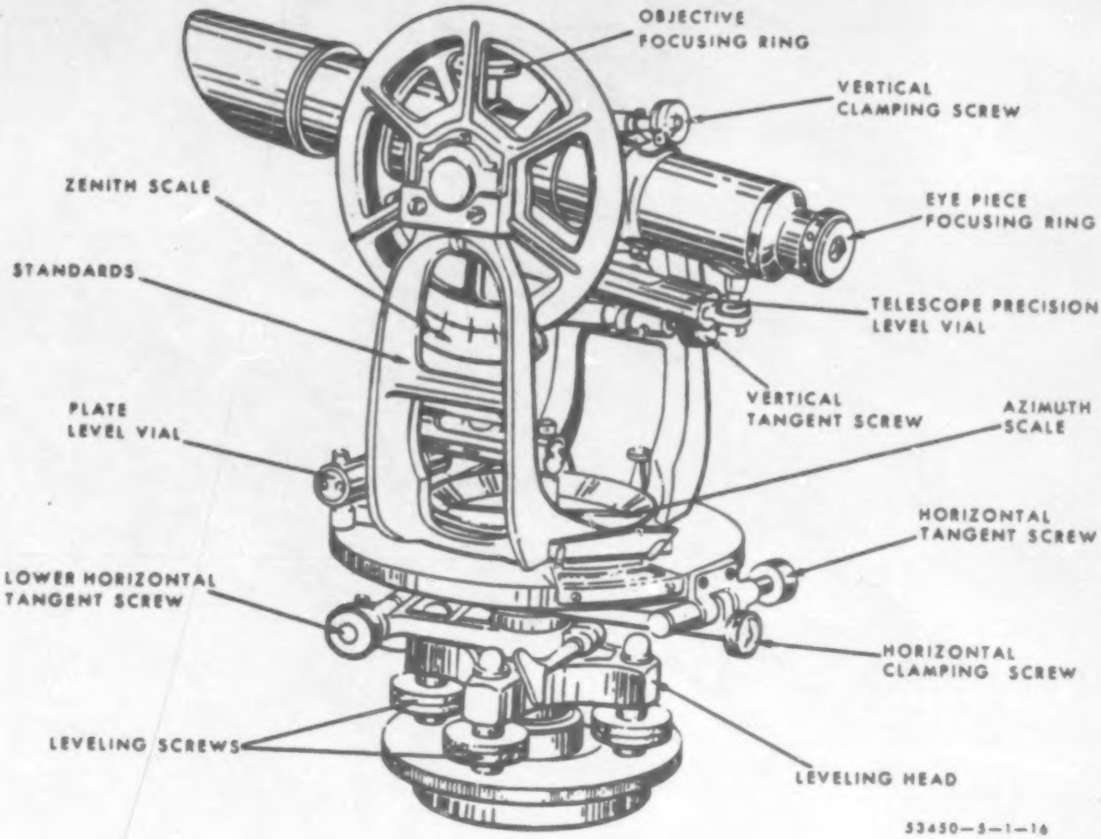

OBJECTIVE FOCUSING RING
VERTICAL CLAMPING SCREW
ZENITH SCALE
EYE PIECE FOCUSING RING
STANDARDS
TELESCOPE PRECISION LEVEL VIAL
VERTICAL TANGENT SCREW
AZIMUTH SCALE
PLATE LEVEL VIAL
HORIZONTAL TANGENT SCREW
LOWER HORIZONTAL TANGENT SCREW
HORIZONTAL CLAMPING SCREW
LEVELING SCREWS
LEVELING HEAD
53450—5—1—16

Figure 20. Transit nomenclature.

11-8. *Leveling screws.* Leveling screws are used to plumb the vertical axis. Some instruments are equipped with three leveling screws, some with four.

11-9. *Vertical clamping screws.* When the vertical clamping screw is released, the telescope may be rotated in either direction about the horizontal axis of the instrument. To lock the vertical vernier (zenith) scale in any position, tighten the vertical clamping screw snugly.

11-10. *Vertical tangent screw.* After the vertical clamping screw has been tightened snugly, the vertical tangent screw is used for any slight movement of the telescope in either direction necessary to attain alignment with the target.

11-11. *Horizontal clamping screws.* When either of these horizontal screws is released, the telescope may be rotated in either direction about the vertical axis of the instrument. The upper horizontal clamping screw controls the inner spindle and is used to lock the horizontal vernier (azimuth) scale to any desired reading. The lower horizontal screw controls the outer spindle and, when tightened, prevent the instrument from rotating.

11-12. *Horizontal tangent screws.* After the lower horizontal clamping screw has been tightened snugly, the lower horizontal tangent screw is used for any slight rotation of the standards in either direction about the vertical axis to attain alignment with the target. The upper horizontal tangent screw aids in the precise setting of the horizontal vernier scale.

11-13. *Level vials.* Level vials are mounted on the transit to aid in rough and precision leveling of the instrument. The plate level vials and the telescope precision level vial differ in sensitivity. One plate level vial is mounted on the upper plate of the instrument parallel to the horizontal axis of the telescope. Another is mounted on one of the standards perpendicular to the horizontal axis of the telescope. The plate level vials are observed when rough-leveling the instrument. The telescope precision level vial is mounted directly onto the telescope, parallel to the optical axis. Coupled with its greater sensitivity, the telescope precision level vial gains a mechanical advantage over the plate level vials by reason of its length and points of suspension.

11-14. **Geometry of the Transit.** There are several geometrical requirements which must be built into and maintained in a transit if accurate results are to be obtained from its use. Three of the most important requirements illustrated in figure 21 are:

(1) The horizontal axis and the vertical axis must be perpendicular to each other.

(2) The optical axis of the telescope must pass through the vertical axis of the instrument.

(3) The optical axis must be perpendicular to the horizontal axis.

NOTE: *Optical equipment erection technical orders and manuals are seldom available to you. For this reason, we will go through the necessary steps you must follow to correctly handle, setup, adjust, and align this precision optical gear. First let's take a look at the transit.*

11-15. **Setup, Adjustment, and Alignment of the Transit.** The necessary sequence that must be followed in the setup, adjustment, and alignment of a transit is as follows:

(1) Set up, adjust, and position the tripod.

(2) Install the mechanical lateral adjuster on the tripod.

(3) Install the transit on the threaded head of the lateral adjuster.

(4) Place the instrument's threaded base squarely on the threaded head of the lateral adjuster.

(5) Position the instrument.

(6) Zero-in the azimuth scale.

(7) Rough-level the instrument.

(8) Buck-in the transit on two established reference points forward of the instrument.

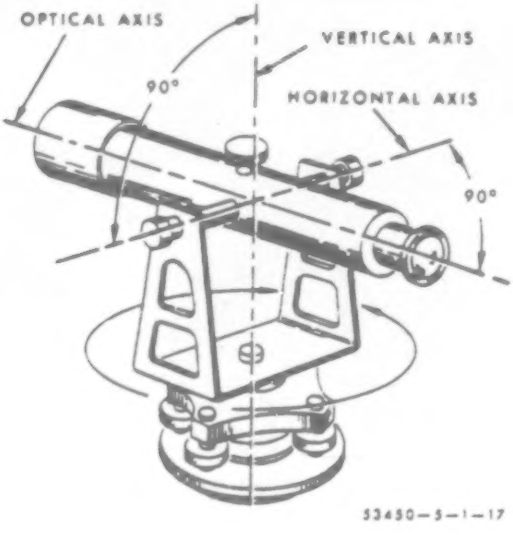


Figure 21. Transit geometry.

(9) Precision-level the transit.

(10) Check the geometry of the transit.

(11) Buck-in the transit between two established points.

11-16. Each of these steps in detailed enough and important enough to the airframe repair specialist for us to consider it separately, though still in the sequence listed here.

11-17. *Set up, adjust, and position the tripod (as illustrated in fig. 22).* To do this:

a. Set up the tripod on an improvised baseplate, placing the points of the tripod legs in the outermost holes of the baseplate.

b. Adjust the tripod to the desired height and lock it in place with the thumbscrews.

c. Position the tripod and baseplate approximately in line with the predetermined reference points.

NOTE: *Maintain a minimum focal distance of at least 6 feet or more from the closest predetermined reference point and the tripod.*

11-18. *Install the mechanical lateral adjuster (crosshead) on the tripod (as illustrated in fig. 23).* To do this:

a. Place the threaded base of the mechanical lateral adjuster squarely on the threaded head of the tripod.

b. Start the threads by turning the mechanical lateral adjuster clockwise until it is seated snugly to the tripod threaded head.

c. Reposition the baseplate with the tripod and lateral adjuster perpendicular to the line established by the reference points.

NOTE: *A recommended focal distance of at least 6 feet or more between the closest reference point and the tripod must be maintained.*

11-19. *Install the transit on the threaded head of the lateral adjuster.* To do this:

a. Remove the transit from its carrying case and release the lower horizontal clamping screw.

b. With one hand grasped firmly on the standard opposite the zenith scale, unscrew the instrument from its baseplate with the other hand, as shown in A of figure 24.

c. Next, with one hand firmly grasped on the standard opposite the zenith scale, lift the instrument carefully from its baseplate, as shown in B of figure 24.

d. Place the other hand under the instrument for support and to carry the instrument to the tripod setup, as shown in C of figure 24.

11-20. *Place the instrument's threaded base squarely on the threaded head of the lateral adjuster.* To do this:

a. Maintain a firm grip on the standard opposite the zenith scale with one hand, and with the other hand start the threads by rotating the

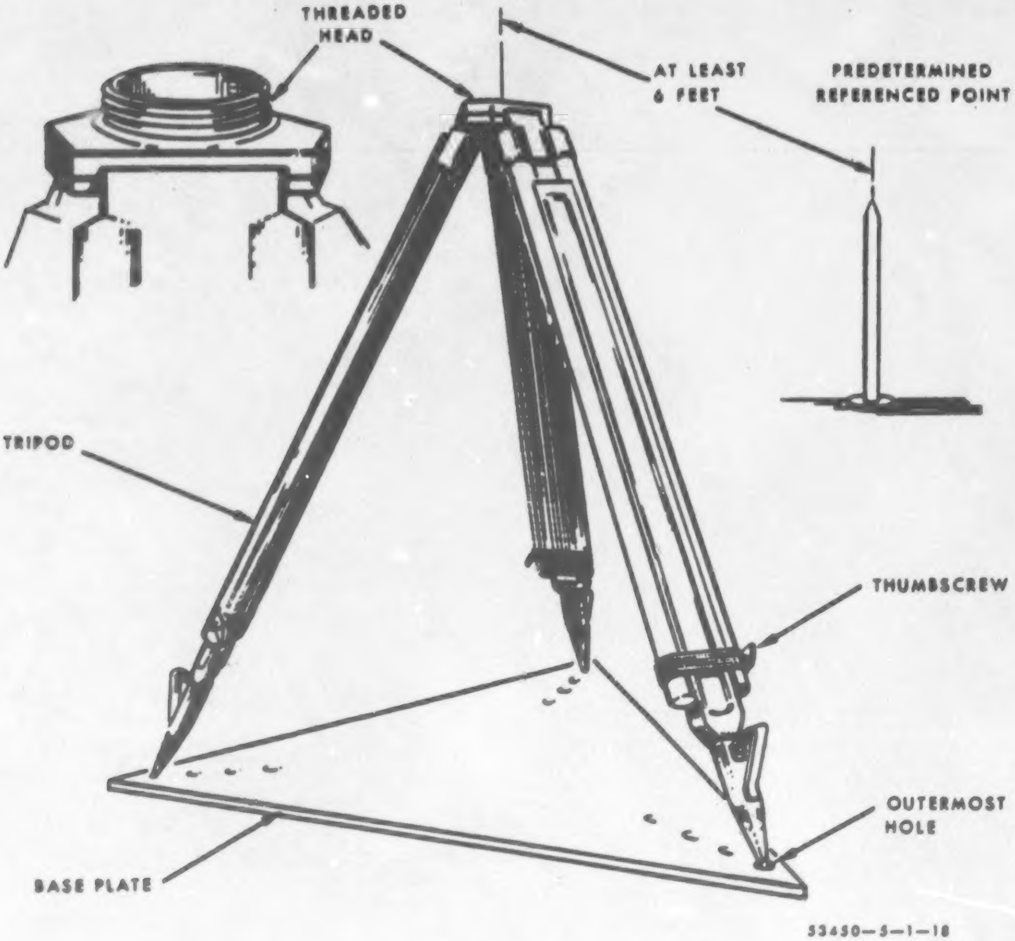

THREADED HEAD
AT LEAST 6 FEET
PREDETERMINED REFERENCED POINT
TRIPOD
THUMBSCREW
OUTERMOST HOLE
BASE PLATE
53450—5—1—18

Figure 22. Positioning of tripod.

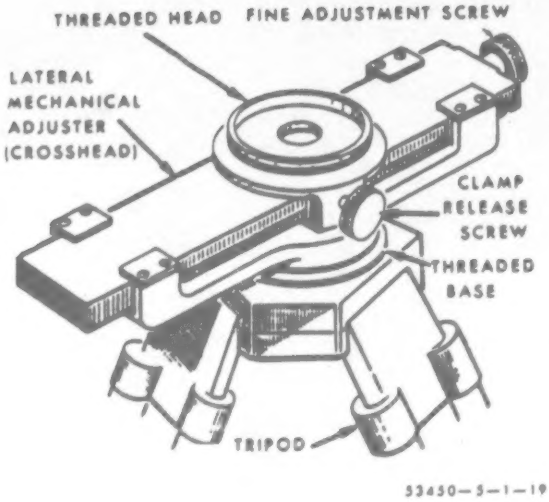

THREADED HEAD
FINE ADJUSTMENT SCREW
LATERAL MECHANICAL ADJUSTER (CROSSHEAD)
CLAMP RELEASE SCREW
THREADED BASE
TRIPOD
53450—5—1—19

Figure 23. Lateral mechanical adjuster.

threaded base of the instrument counterclockwise until you hear a click, indicating that the threads are meshed, as shown in figure 24.

b. Now turn the threaded base of the instrument clockwise until it is seated snugly to the threaded head of the lateral adjuster.

11-21. *Position the instrument.* To do this:

a. Try all clamps and motions of the instrument to make sure the instrument is in good operating condition.

b. Loosen all leveling screws.

c. Rotate the leveling head of the transit to bring two opposite leveling screws perpendicular to the line of sight being established.

NOTE: *At this point, the lower horizontal tangent screw should be positioned in front of the instrument facing toward the reference points.*

d. Lock the instrument in place by tightening all the leveling screws snugly. NOTE: *Leveling screws must be tightened to a proper tension.*

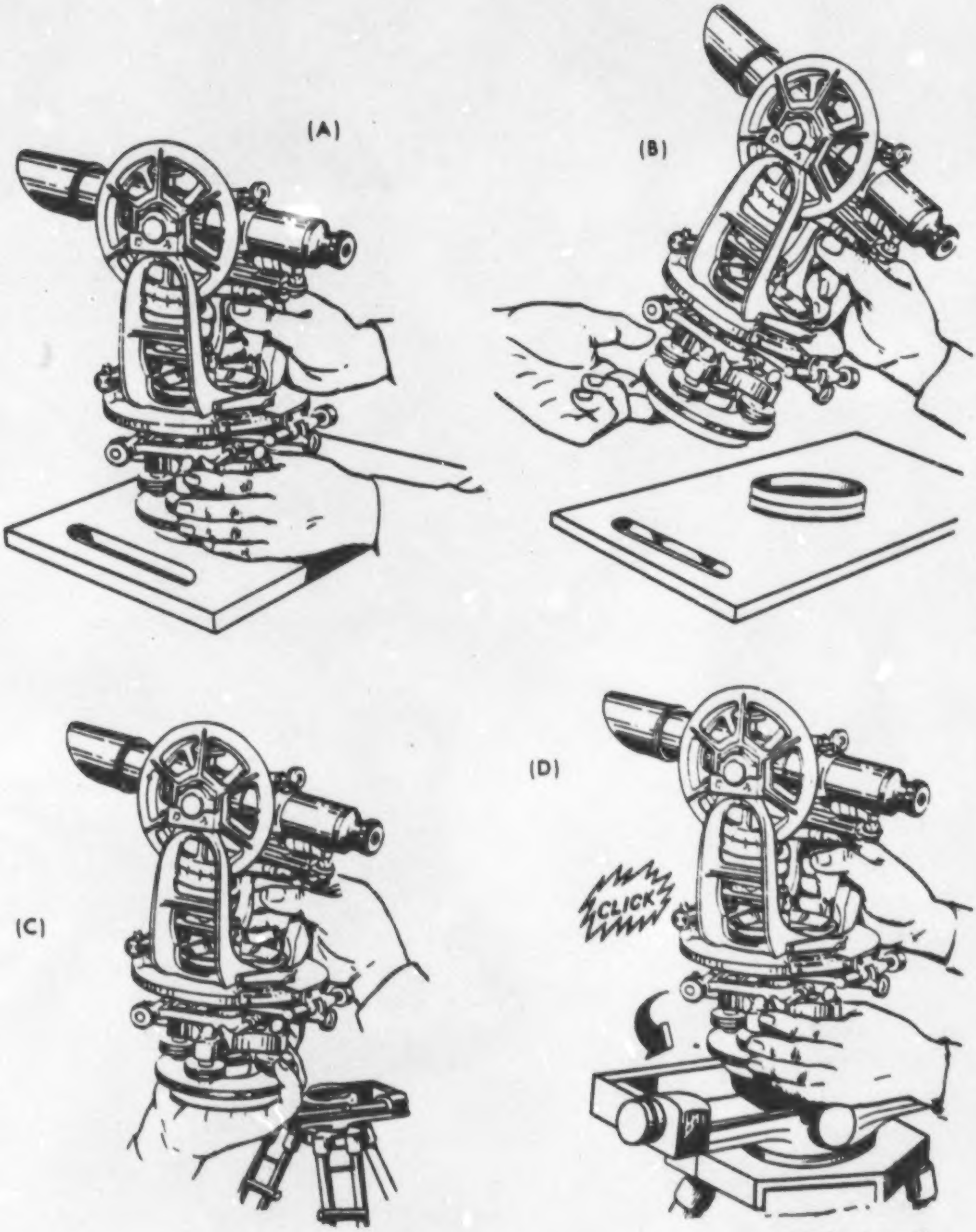

(A)
(B)
(C)
(D)
CLICK
33430-3-1-20

Figure 24. Placing transit on tripod.

Leveling screws that are too tight cause creeping and damage to the instrument. Screws that are too loose do not give the instrument firm support.

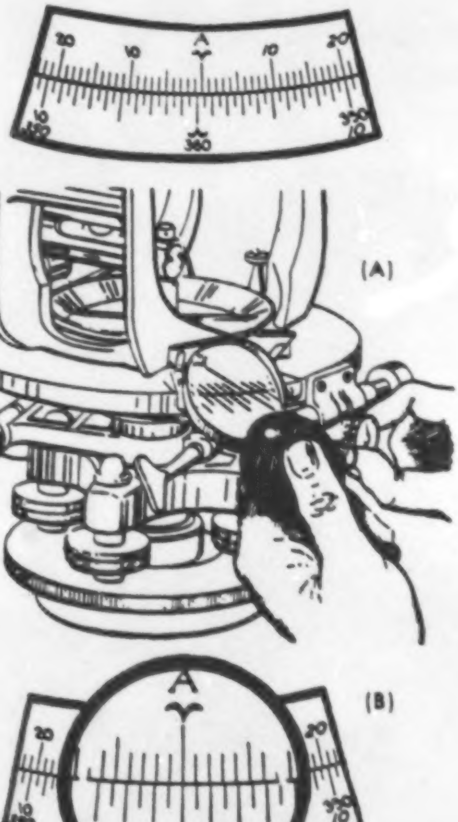
11-22. *Zero-in the azimuth scale.* To do this:

a. Release the upper horizontal clamping screw.

b. Rotate the instrument in azimuth until the "A" indicator on the azimuth scale aligns closely with the 360° over 0° graduations of the scale (without magnifying glass), as shown in A of figure 25.

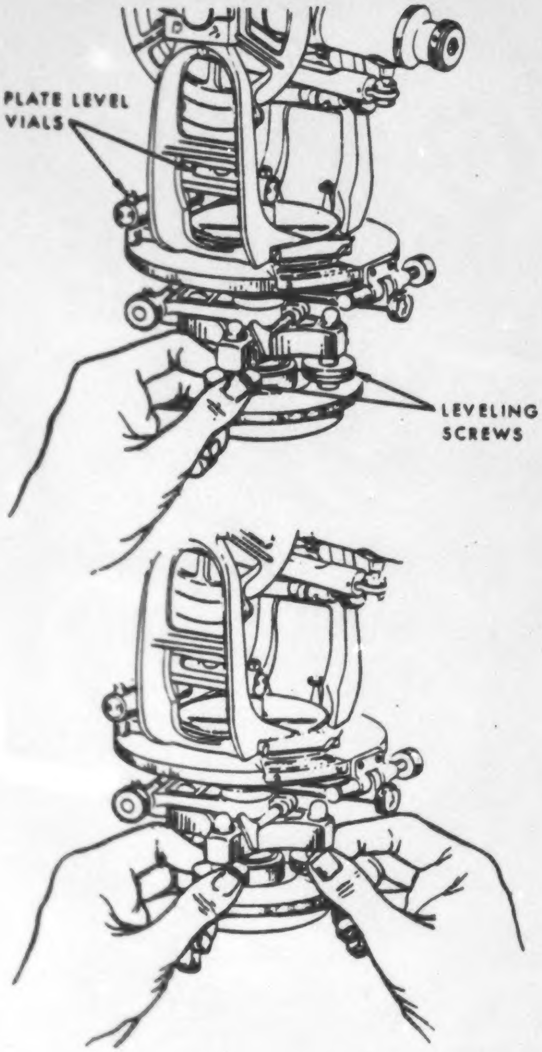
c. Lock the upper horizontal clamping screw.

d. Using a magnifying glass and the upper horizontal tangent screw, set the "A" indicator of the azimuth scale in perfect coincidence with the 360° over 0° graduations of the scale, as illustrated in B of figure 25.



53450-5-1-21

Figure 25. Zero in the azimuth scale.



53450-5-1-22

Figure 26. Centering the bubble.

11-23. *Rough-level the instrument.* To do this:

a. Release the lower horizontal clamping screw.

b. Rotate and position the transit about its vertical axis so that the telescope is parallel to the line of sight and directly over two opposite leveling screws.

c. Lock the transit in place by tightening the lower horizontal clamping screw.

d. Center the bubbles within each plate level vial by adjusting the proper pair of opposite leveling screws. The bubble in each plate vial is centered, adjusting the leveling screws that are parallel to that plate level vial, as illustrated in figure 26.

Note: *The two opposite leveling screws are always turned at the same time in opposite directions to each other. The travel of the bubble within each plate vial is controlled by the direction in which the level screw is turned by the left thumb.*

11-24. *Buck-in the transit on two established reference points forward of the instrument.* To do this:

a. Sight-in the far erference point. (A graduated scale can be used as the target.)

Note: *From this step on, or whenever the instrument will be used for sighting in, taking readings establishing reference points, etc., it will be necessary to focus the telescope, adjust the telescope eyepiece until the crosshairs are sharp and clear, and check for and eliminate parallax.*

b. With the lower horizontal tangent screw, rotate the instrument until the vertical crosshair is in perfect coincidence with the desired scale graduation (target).

c. Release the vertical clamping screw.

d. Transit the telescope and sight in the near scale (target).

e. Lock the vertical clamping screw.

f. Observe and note the displacement from the desired graduation on the near scale (target).

g. Next, move the transit by means of the crosshead (lateral adjuster). while observing the near scale through the telescope, until its vertical crosshair is moved in the direction of, and approximately half of the displacement beyond, the desired scale graduation.

h. Repeat the previous steps until the telescope's vertical crosshair is in perfect coincidence on the same desired graduation of both near and far scales (targets).

11-25. *Precision-level the transit.* To do this:

a. Release the vertical clamping screw and transit the telescope up and down by hand until an approximate level position is indicated by the telescope precision level vial. The reading on the zenith scale should be approximately 0°, as shown in figure 27.

b. Tighten the vertical clamping screw.

c. Center the telescope precision bubble by adjusting the vertical tangent screw.

d. Release the lower horizontal clamping screw, rotate the instrument 180° about its vertical axis and lock the lower horizontal clamping screw.

e. If the bubble within the telescope level is not centered, correct half of the observed error with the vertical tangent screw and the other half with the leveling screws that are directly under the telescope.

f. Return the telescope to the initial position to check the setting and correct setting if necessary.

g. Rotate the instrument 90° about its vertical axis and correct any error by adjusting only the two opposite leveling screws that are directly under the telescope until the precision level vial is centered in this position.

h. Check the instrument for level, at each quarter (90°) turn, over the leveling screws.

i. If the telescope precision level vial does not remain centered, repeat the four previous steps.

j. Align the instrument to the reference points.

11-26. *Check the geometry of the transit.* To do this:

a. Establish a third reference point which requires transiting the telescope through an arc equal to or greater than that necessary to locate the points involved.

b. Release the lower horizontal clamping screw and rotate the instrument 180° about its vertical axis.

c. Lock the transit in position.

d. Release the vertical clamping screw and transit the telescope 180° about its horizontal axis.

e. Transit the telescope and sight-in the more distant of the two alignment points.

f. Transit the telescope and sight-in the nearest alignment point and the third point, respectively.

Note: *If the vertical crosshair is still aligned with these points, the instrument is considered accurate.*

11-27. *Buck-in the transit between two established points.* To do this:

a. Setup, adjust, and align the instrument approximately halfway between the established points following the first six major steps.

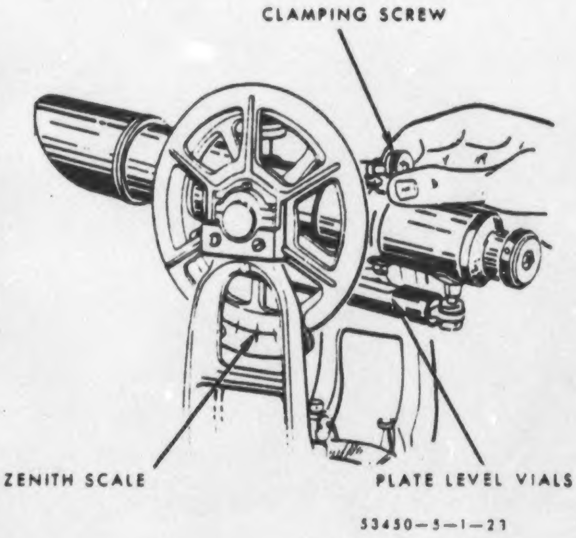


Figure 27. Precision level position.

b. Release the lower horizontal clamping screw and sight-in the forward reference point, using a graduated scale as the target. Lock the instrument in place.

NOTE: *From this point on, or whenever the instrument is used for sighting in, taking readings, measurements, etc., it will be necessary to focus the telescope, adjust the telescope eyepiece until the crosshairs are sharp and clear, and check for and eliminate parallax.*

c. With the lower horizontal tangent screw, rotate the instrument until the vertical crosshair of the telescope is in perfect coincidence with the desired scale graduation (target).

d. Release the vertical clamping screw, transit the telescope, and sight-in the aft scale (target). Lock the telescope in place.

e. Observe and note the displacement from the desired graduation on the aft scale (target).

f. Now, move the transit by means of the crosshead (lateral adjuster) half the distance of the displacement in the direction of the desired scale graduation.

g. Repeat the previous five steps until the telescope crosshairs are in perfect alignment (coincidence) with the same desired graduations of both aft and forward scales.

Our next item in the discussion of optical equipment is auto-reflection equipment and its use.

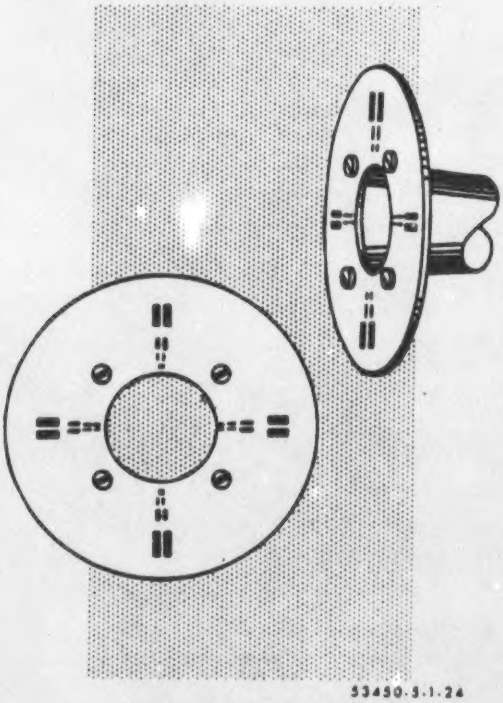


Figure 28. Auto-reflection target.

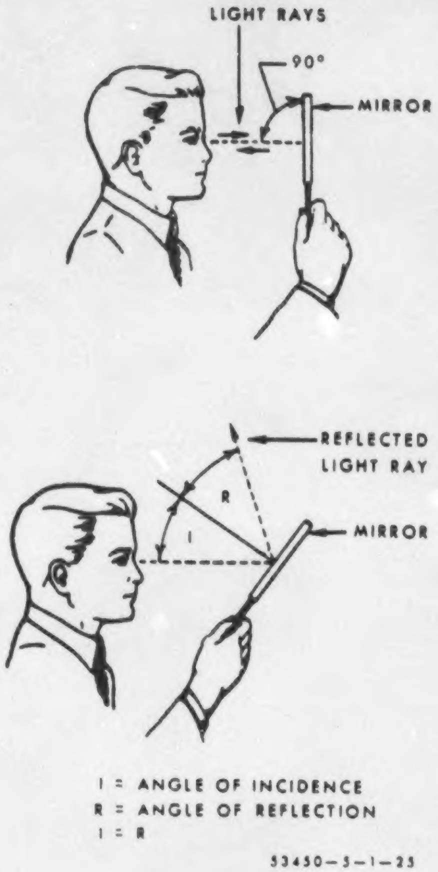


Figure 29. Auto-reflection principles.

12. Auto-Reflection Equipment

12-1. In the past, the transit was used to establish reference planes which were perpendicular to the line of sight. This was an extremely difficult and time-consuming procedure.

12-2. Recently, improved methods based on auto-reflection have been devised to assist in the establishment of perpendicular planes. Auto-reflection is the act of looking through a telescope at a mirror and viewing an image of a target that is attached to the telescope. Figure 28 shows a typical auto-reflection target that can be attached to a telescope. We will cover auto-reflection, first the principles, the auto-reflection mirror, the accuracy of auto-reflection, tolerances, and finally the sequences necessary to properly setup the auto-reflection equipment.

12-3. Four sets of dash marks (at 90° to each other) on the target make it possible to center the target image on the cross hairs of the telescope. The dash marks nearest the center of the target are 0.010-inch apart, which helps the ob-

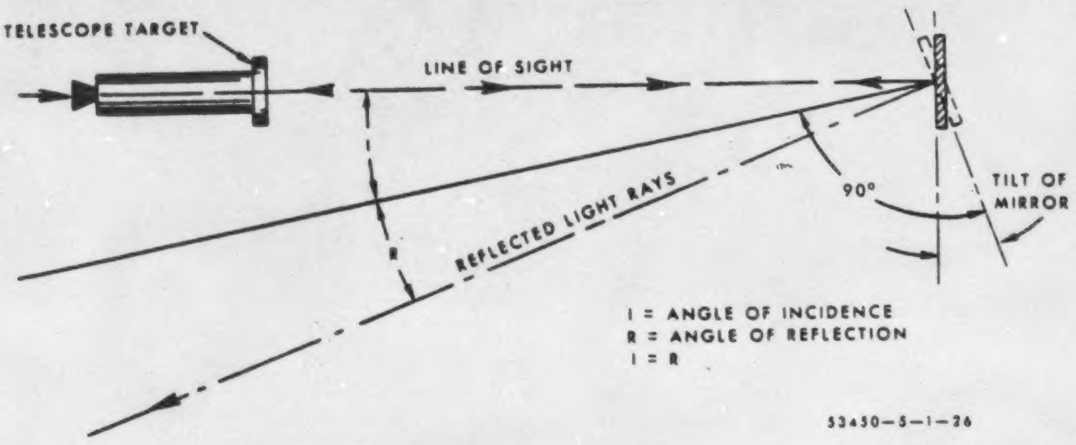


Figure 30. Telescope target and mirror.

server to center the target image on the crosshairs.

12-4. **Principles.** Auto-reflection is based on the simple principles of reflection of light from a flat mirror. It is similar to what takes place when a person holds a mirror in front of his face and looks into it. If he turns or tilts the mirror far enough, the person will not be able to see himself. This is true because the light reflected from his face strikes the mirror and obeys the law of reflection which states that the angle of reflection is equal to the angle of incidence, as illustrated in figure 29.

12-5. Figure 29 illustrates that if the person moves the mirror back into a position where it is perpendicular with his line of sight, he will then be able to see himself. Light rays which strike a mirror on a path perpendicular to the mirror return to the same path from which they come.

12-6. The same principles apply if a target is mounted on the end of a telescope and a mirror is viewed. If the mirror is tilted far enough from the line of sight, either vertically or horizontally, the target cannot be seen in the mirror, as shown in figure 30.

12-7. Suppose, however, that the mirror is adjusted so that it is exactly perpendicular to the line of sight, as in figure 31. Light rays approaching the target along the line of sight will then be reflected back along the same path. As a result, the observer looking through the telescope will see the dash marks of the target image centered on the crosshairs. This is known as a *zero-zero* reading because there is no displacement of the target image and no tilt of the mirror in either direction.

12-8. In auto-reflection, the observer must always focus the telescope to twice the distance between the telescope target and the mirror. This is done because, in reflection from a flat mirror, the image of an object seen in a mirror appears to be at a distance behind the mirror, which is equal to the distance of the object in front of the mirror. Any slight movement of the mirror from its perpendicular position will be shown by dash marks of the target image moving across the crosshairs, as demonstrated in figure 32.

12-9. **Auto-Reflection Angle Mirror.** All mirrors must be coated with reflective coatings. Mirrors coated on the back are not satisfactory for

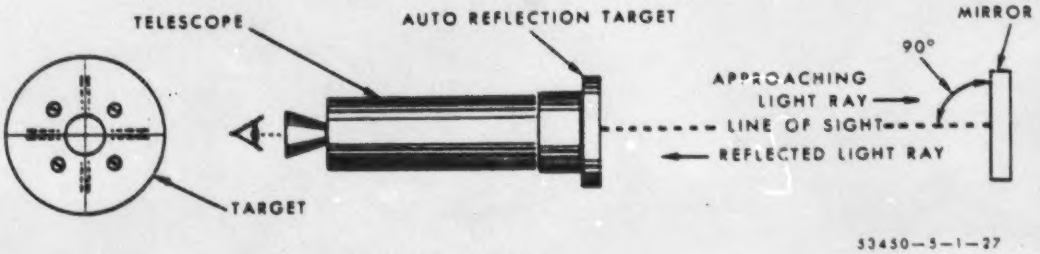


Figure 31. Zero-zero reading.

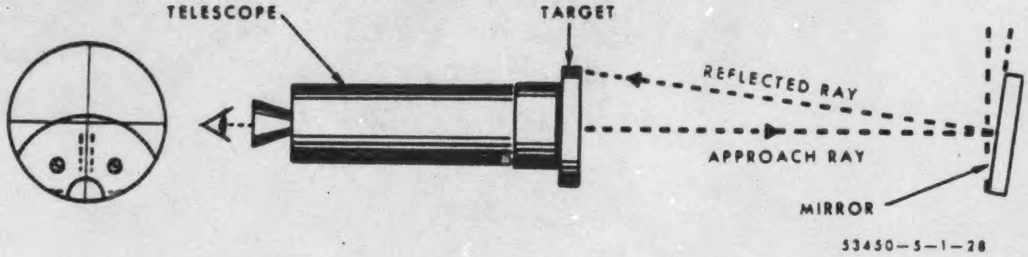


Figure 32. Mirror titled, target image moves.

auto-reflection, because a certain amount of light is reflected from the front surface, which causes multiple images. Therefore, the mirrors used in auto-reflection, as illustrated in figure 33, are all front-surfaced mirrors. This means that the surface facing the telescope is the mirrored surface. The mirrors are coated with either aluminum or chromium.

12-10. The mirrors are checked by precision inspection for flatness so that regular reflection will occur when they are used. These mirrors are flat within 17/1,000,000-inch. Several sizes of mirrors are available. A suitable box is supplied for storage when the mirros are not in use.

12-11. The base of the mirror is more or less the base of a transit. This permits the measuring of angles when the mirror is turned to the right or left of the vertical axis.

12-12. When you clean these front-surfaced mirrors, be extra careful to avoid scratching; and investigate thoroughly the possible action of a solvent upon such a surface. It is safe to use a soap solution, but clean exclusively by flushing whenever possible.

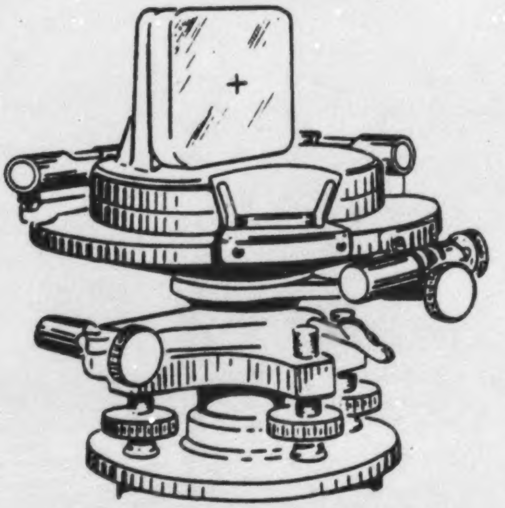


Figure 33. Auto-reflection angle mirror.

12-13. Never touch the mirrored surface with your fingers. Handle it from the base. Never wipe the mirrored surface. Cleaning fluid and optical cleaning paper should be kept available.

12-14. **Accuracy and Sensitivity of Auto-Reflection.** Two reasons make auto-reflection a very accurate and simple means of establishing a perpendicular to the line of sight.

12-15. First, the apparent angle of error shown by the target image moving across the crosshairs is always double the actual angle by which the mirror and object have been tilted. This is shown in figure 34. When the mirror is perpendicular to the line of sight, light rays traveling along the line of sight strike the mirror and are reflected back along the same path. But suppose that the mirror is tilted 5° out of perpendicular. The normal of the mirror will then be 5° from the line of sight.

12-16. Now suppose that the light rays travel toward the mirror along the line of sight. The angle of incidence (*I*) will be 5°. Therefore, the angle of reflection (*R*) will also be 5°. As a result, the incident ray (approaching ray) and reflected ray will be 10° apart. In short, when the mirror was perpendicular, the light rays traveled to and from the mirror along the same path. When the mirror was tilted 5°, the paths by which the light rays traveled to and from the mirror was separated by an angle of 10°. This apparent doubling of the angle of error makes auto-reflection a very accurate means of erecting perpendiculars.

12-17. The second reason is that the target reading for the same angular deviation increases as the mirror is moved away from the telescope. This is shown by the illustrations in figure 35.

12-18 **Tolerances in Auto-Reflection Readings.** Accuracy is important in using auto-reflection. However, certain tolerances apply in erecting perpendicular planes, just as in any other system of alignment.

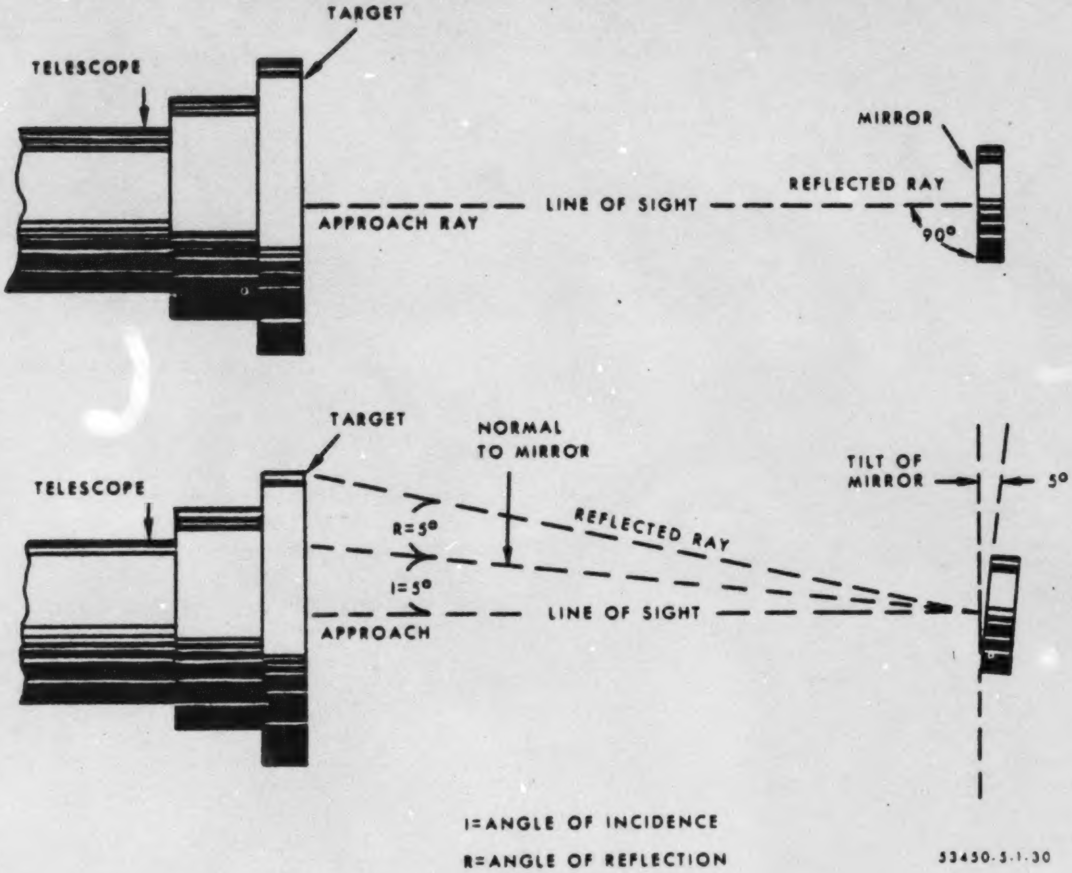

TARGET
TELESCOPE
MIRROR
REFLECTED RAY
LINE OF SIGHT
APPROACH RAY
90°
TARGET
NORMAL TO MIRROR
TELESCOPE
TILT OF MIRROR
5°
REFLECTED RAY
R=5°
I=5°
LINE OF SIGHT
APPROACH
I=ANGLE OF INCIDENCE
R=ANGLE OF REFLECTION
53450-5-1-30

Figure 34. Apparent doubling of angle error.

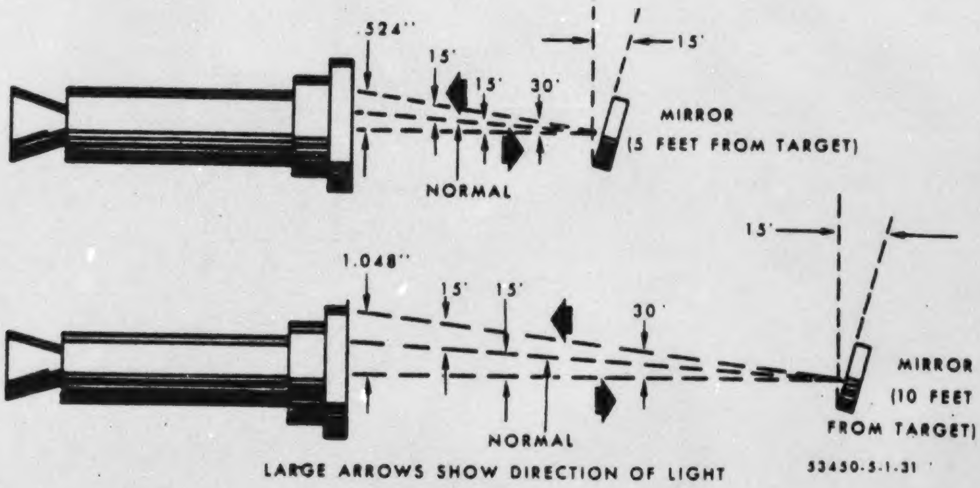

.524''
15'
15'
30'
15'
MIRROR
(5 FEET FROM TARGET)
NORMAL
15'
1.048''
15'
15'
30'
MIRROR
(10 FEET FROM TARGET)
NORMAL
LARGE ARROWS SHOW DIRECTION OF LIGHT
53450-5-1-31

Figure 35. How distance affects reading.

12-19. As we have pointed out, the reading for a given amount of tilt will vary according to the distance involved. This can be calculated by means of trigonometric functions. The chart in figure 36 shows target readings for given amounts of tilt in the mirror at different distances of the mirror from the telescope.

12-20. **Sequences of Setup of Auto-Reflection Mirror.** The sequence requirements necessary to properly set up the auto-reflection mirror are as follows:

- Set up, adjust, position, and buck-in the transit on two established reference points forward of the instrument.
- Set up, adjust, and position a tripod on an improvised tripod stabilizer.
- Install the mechanical lateral adjuster (crosshead) on the tripod setup.
- Mount the auto-reflection angle mirror on the threaded head of the crosshead lateral adjuster.
- Position the instrument.
- Zero-in the azimuth scale.
- Rough-level the instrument.
- Check the height adjustment of the auto-reflection angle mirror.
- Buck-in the auto-reflection angle mirror.
- Accurately level the auto-reflection angle mirror.
- Check the summetry of the auto-reflection angle mirror.
- Establish auto-reflection.

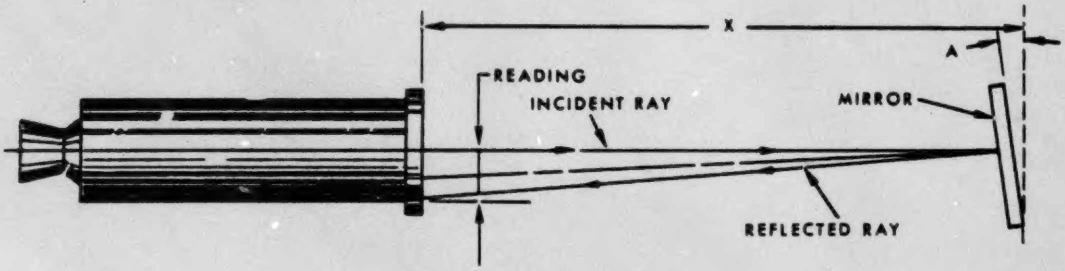
12-21. There are enough details to each of these steps, and each is important enough to the airframe repair specialist, for us to consider each separately, though still in the sequence listed here.

12-22. *Set up, adjust, position, and buck-in the transit on two established reference points forward of the instrument.*

12-23. *Set up, adjust, and position a tripod (as shown in fig. 37) on an improvised tripod stabilizer.* Do this approximately in the line of sight established by the transit.

12-24. *Install the mechanical lateral adjuster (crosshead) on the tripod setup (as shown in fig. 38).* To do this:

a. Remove the cap from the threaded head of the tripod.



A=DEVIATION FROM PERPENDICULAR
X=DISTANCE FROM TELESCOPE TO MIRROR IN FEET
READING=DISTANCE BETWEEN CENTER OF CROSS HAIRS AND CENTER OF TARGET IMAGE

53450—5—1—32

Readings for Different Amounts of Tilt in Mirror				
Distance between Mirror and Telescope Target in Feet (X)	15" (sec) Tilt = .00087 in/ft	30" (sec) Tilt = .00174 in/ft	45" (sec) Tilt = .00261 in/ft	60" (1 min) Tilt = .00348 in/ft
	Reading =	Reading =	Reading =	Reading =
5	.0087	.0174	.0261	.0348
6	.0104	.0208	.0312	.0416
8	.0139	.0278	.0417	.0556
10	.0174	.0348	.0522	.0696
12	.0208	.0416	.0624	.0832
14	.0244	.0488	.0732	.0976
16	.0278	.0556	.0834	.1112

Figure 36. Target readings for angular deviations at a given distance.

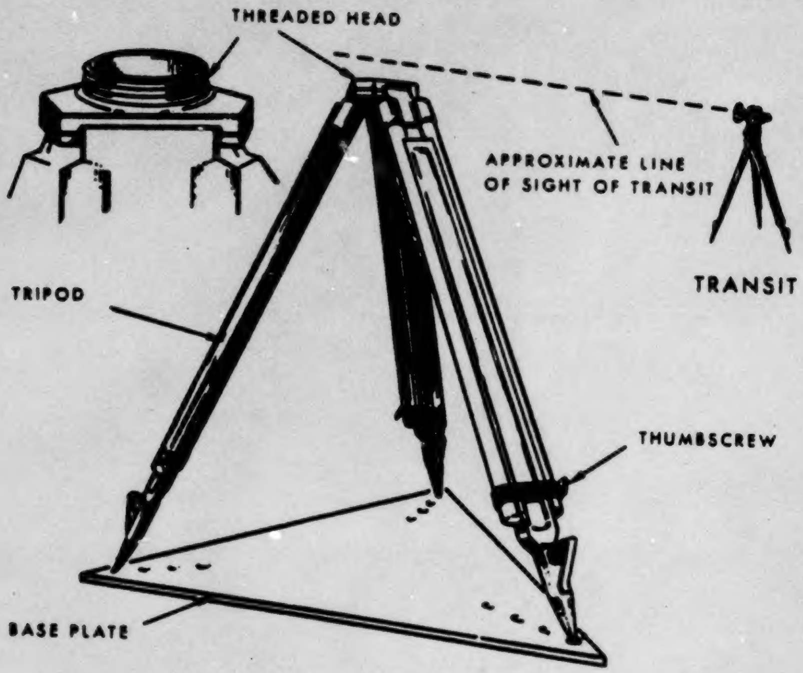

THREADED HEAD
APPROXIMATE LINE OF SIGHT OF TRANSIT
TRANSIT
TRIPOD
THUMBSCREW
BASE PLATE
53450—5—1—33

Figure 37. Tripod position.

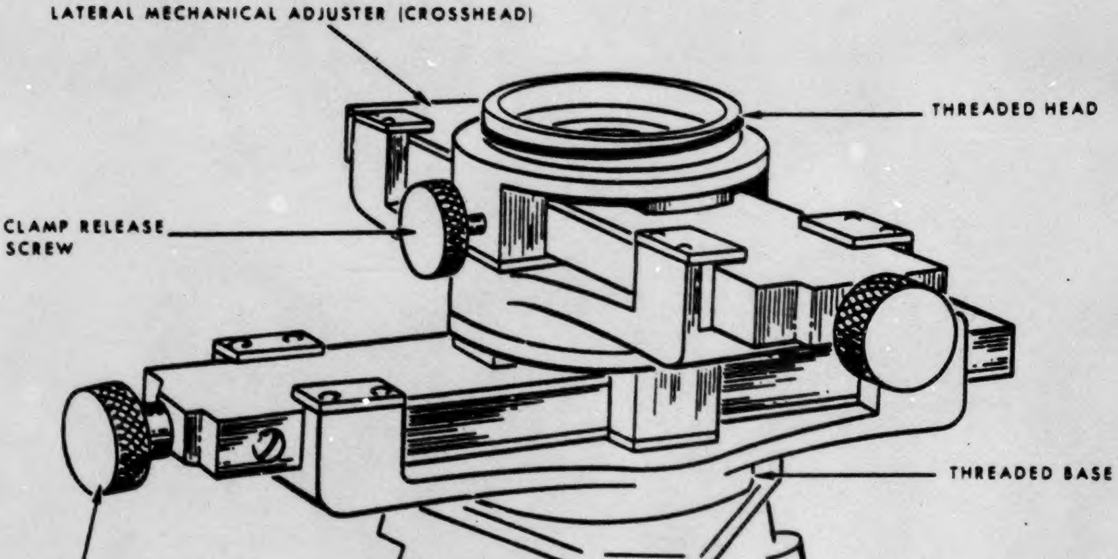

LATERAL MECHANICAL ADJUSTER (CROSSHEAD)
THREADED HEAD
CLAMP RELEASE SCREW
THREADED BASE
FINE ADJUSTMENT SCREW
TRIPOD
53450—5—1—34

Figure 38. Installation of crossfeed.

b. Place the threaded base of the crosshead squarely on the threaded head of the tripod.

c. Start the threads by turning the crosshead counterclockwise until you hear a click, indicating that the threads are meshed.

d. Next, turn the crosshead clockwise until it is seated snugly on the threaded head of the tripod.

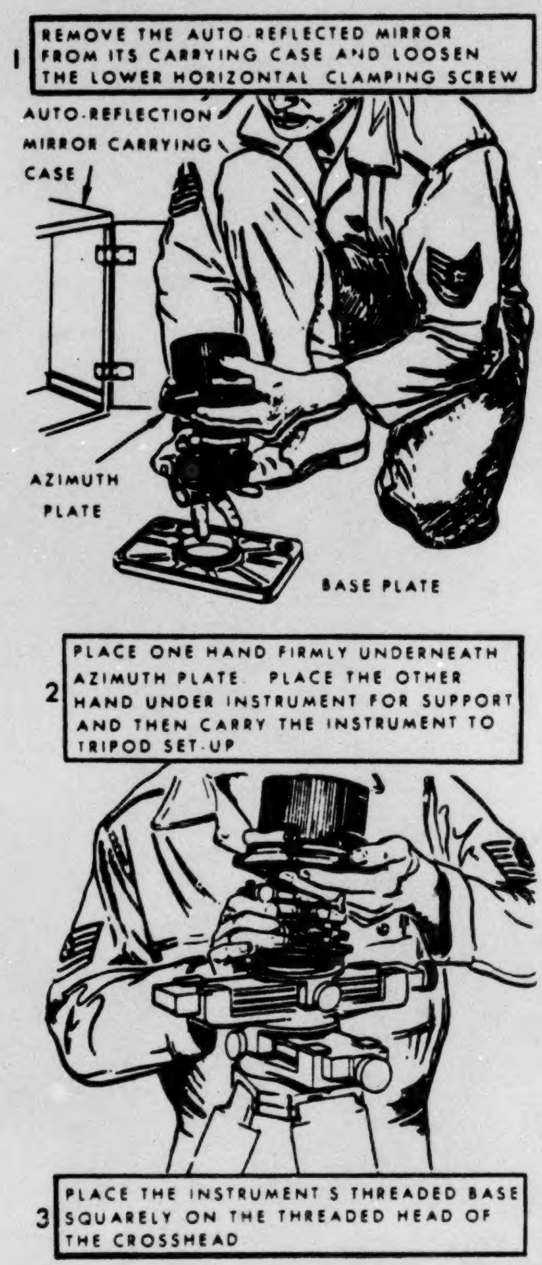

1
REMOVE THE AUTO REFLECTED MIRROR FROM ITS CARRYING CASE AND LOOSEN THE LOWER HORIZONTAL CLAMPING SCREW
AUTO-REFLECTION MIRROR CARRYING CASE
AZIMUTH PLATE
BASE PLATE
2
PLACE ONE HAND FIRMLY UNDERNEATH AZIMUTH PLATE. PLACE THE OTHER HAND UNDER INSTRUMENT FOR SUPPORT AND THEN CARRY THE INSTRUMENT TO TRIPOD SET-UP
3
PLACE THE INSTRUMENT S THREADED BASE SQUARELY ON THE THREADED HEAD OF THE CROSSHEAD
53450 S.1.35

Figure 39. Mounting auto-reflection angle mirror.

e. Center the threaded head and bar of the crosshead. The threaded head should be centered so that it will have equal travel adjustment on the crosshead.

f. Now reposition the tripod setup so that the attached crosshead will travel perpendicular to the line of sight of the established reference points.

12-25. *Mount the auto-reflection angle mirror on the threaded head of the crosshead lateral adjuster (as shown in fig. 39).* To do this:

a. Remove the auto-reflection angle mirror from its carrying case and loosen the lower horizontal clamping screw.

b. Place one hand underneath the azimuth plate, hold firmly, then unscrew the instrument from its baseplate with the other hand.

c. Next, with one hand placed underneath and grasping the azimuth plate firmly, lift the instrument carefully from the baseplate.

d. Place the other hand under the instrument for support and carry this instrument to the tripod set up.

e. Place the instrument's threaded base squarely on the threaded head of the crosshead.

f. Maintaining a firm grip underneath and on the azimuth plate with one hand, with the other start the threads by rotating the threaded base of the instrument counterclockwise until you hear a click, indicating that the threads have meshed.

g. Now turn the threaded base of the instrument clockwise until it is seated snugly to the threaded head of the lateral adjuster.

12-26. *Position the instrument (as shown in fig. 40).* To do this:

a. Try all clamps and motions of the instrument to make sure that the instrument is in good operating condition.

b. Loosen all leveling screws.

c. Rotate the leveling head of the auto-reflection angle mirror to bring two opposite leveling screws perpendicular to the line of sight of the transit. NOTE: *At this point, the lower horizontal tangent screw should be positioned to the rear of the instrument facing the operator.*

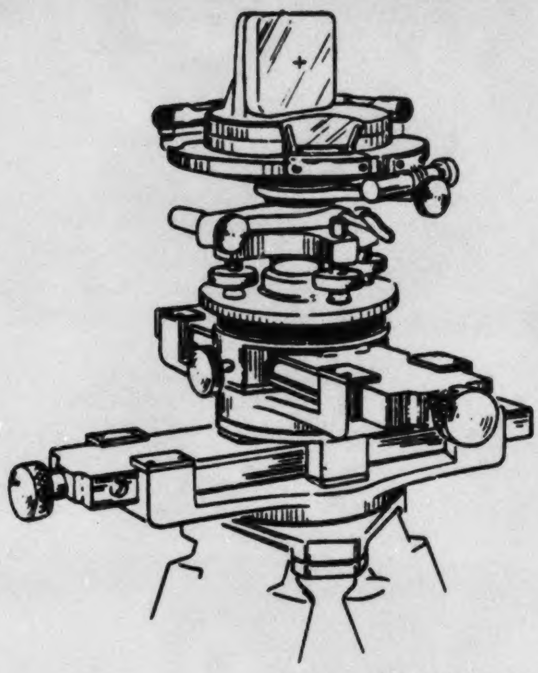
d. Center the leveling head on the threaded head of the instrument.

e. Lock the instrument in place, tightening all leveling screws snugly. NOTE: *Leveling screws must be tightened to a proper tension. Leveling screws that are too tight cause creeping and damage to the instrument. Screws that are too loose do not give the instrument firm support.*

12-27. *Zero-in the azimuth scale.* To do this:

a. Loosen the upper horizontal clamping screw.

b. Rotate the instrument in azimuth until the "A" indicator of the azimuth scale aligns closely in line with the 360° over 0° graduations of the



53450—5—1—36

Figure 40. Positioning instrument.

scale. Do not use a magnifying glass at this time, (A of fig. 41).

c. Tighten the upper horizontal clamping screw.

d. Using a magnifying glass and the upper horizontal tangent screw, set the "A" indicator of the azimuth scale in perfect coincidence with the 360° over 0° graduations of the scale (B of fig. 41).

12-28. *Rough-level the instrument.* To do this:

a. Tighten the lower horizontal clamping screw.

b. Rotate and position the auto-reflection angle mirror about its vertical axis so that the plate level vials are parallel to a pair of opposite leveling screws.

c. Tighten the lower horizontal clamping screw to secure the instrument in place.

d. Center the bubbles within each plate level vial by adjusting the proper pair of opposite leveling screws. The bubble in each plate level vial is centered by adjusting the leveling screws that are parallel to that plate level vial. NOTE: *The two opposite leveling screws are always turned at the same time in opposite direction to each other. The travel of the bubble within each plate level vial is controlled by the direction in which the leveling screw is turned by the left thumb.*

12-29. *Check the height adjustment of the auto-reflection angle mirror (as shown in fig. 42).* To do this:

a. Remove the cover cap from the auto-reflection angle mirror.

b. Sight-in the transit on the mirror surface of the auto-reflection angle mirror.

c. Observe and note, as shown in figure 42, the displacement of the horizontal line of the small cross on the mirror's surface and the horizontal crosshair of the transit's telescope.

d. Raise or lower the mirror's tripod setup until the horizontal line of the small cross on the mirror's surface is approximately the same height as the horizontal crosshair in the transit's telescope when viewed through the transit telescope. NOTE: *The auto-reflection angle mirror must be rough-leveled after each height adjustment.*

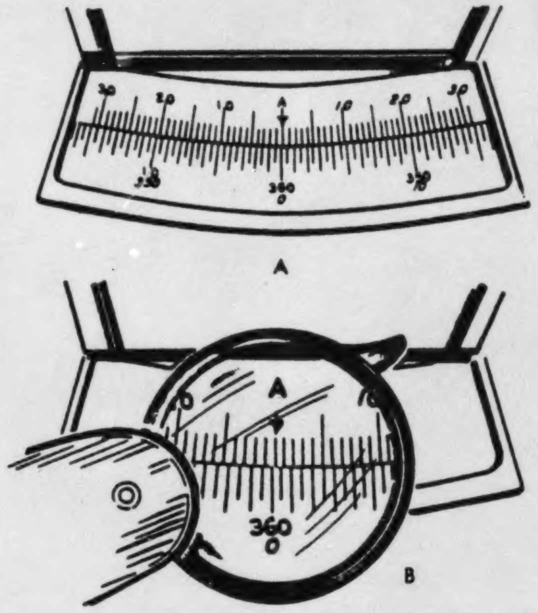
12-30. *Buck-in the auto-reflection angle mirror.* To do this:

a. Sight-in the small cross on the mirror's surface through the transit telescope.

b. Observe and note, as shown in figure 43, the displacement of the vertical line of the small cross on the mirror's surface and the vertical crosshair of the transit's telescope.

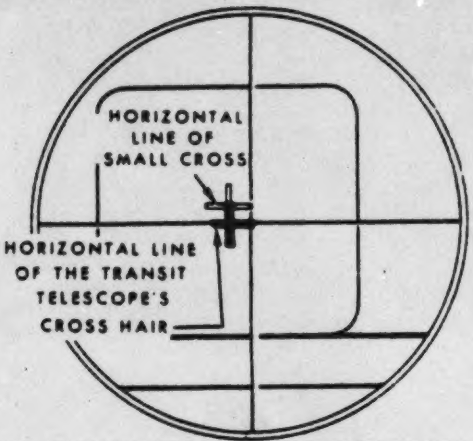
c. Move the auto-reflection angle mirror to the transit's line of sight by means of the crosshead (lateral adjuster).

d. Loosen the clamp release screw of the lateral adjuster.



53450—5—1—37

Figure 41. Zeroing in the azimuth scale.


HORIZONTAL LINE OF SMALL CROSS
HORIZONTAL LINE OF THE TRANSIT TELESCOPE'S CROSS HAIR

LOWER THE MIRROR S TRIPOD SET-UP UNTIL THE SMALL CROSS HORIZONTAL LINE IS THE SAME HEIGHT AS THE CROSS HAIR HORIZONTAL LINE

53450 5 1 38

Figure 42. Checking height adjustment.

e. Move the auto-reflection angle mirror in the direction of and approximately on the line of sight of the transit.

f. Tighten the clamp release screw of the lateral adjuster.

g. With the fine adjustment of the lateral adjuster, buck-in the auto-reflection angle mirror until the vertical line of the small cross on the mirror's surface coincides perfectly with the vertical crosshair of the transit's telescope. NOTE: *To accomplish a buck-in operation, one operator observes the coincidence of the vertical line and the vertical crosshair through the transit telescope, and the other operator adjusts the movement of the auto-reflection angle mirror by means of the lateral adjuster (crosshead).*

12-31. *Accurately level the auto-reflection angle mirror.* To do this:

a. Check both plate level vials, and rough-level the instrument if necessary.

b. Loosen the lower horizontal clamping screw, rotate the instrument 180° about its vertical axis, and tighten the lower horizontal clamping screw.

c. If the bubbles within each plate vial are not centered, correct half of the observed error by adjusting each of the two opposite leveling screws that are parallel to the plate level vial.

12-32. *Check the symmetry of the auto-reflection angle mirror.* To do this:

a. Sight-in the small cross on the mirror's surface through the transit's telescope.

b. Release the lower horizontal clamping screw.

c. Observe the small cross on the mirror's surface through the transit telescope and rotate the auto-reflection angle mirror approximately 80° to the left, then to the right, in azimuth. NOTE: *If the vertical line of the small cross on the mirror's surface appears to move in respect to the vertical crosshairs of the transit's telescope, either the small cross on the mirror's surface is not on the vertical axis or the mirror is not conicident to the vertical axis. If either of these conditions is evident, the auo-reflection angle mirror must be adjusted by a competent instrument technician.*

12-33. *Establish auto-reflection.* To do this:

a. Look over the top and along the line of sight of the transit's telescope and observe the auto-reflection angle mirror.

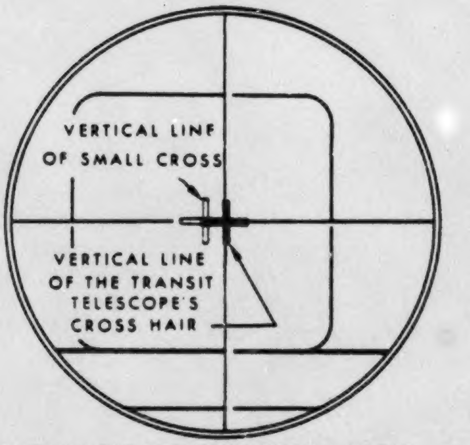
b. Loosen the lower horizontal clamping screw of the auto-reflection angle mirror.

c. Rotate the auto-reflection angle mirror until an image of the auto-reflection target mounted on the end of the telescope can be seen in the mirror.

d. Tighten the lower horizontal clamping screw of the auto-reflection angle mirror.

e. Sight-in and focus the transit telescope (twice the distance from the transit telescope to the mirror to obtain auto-reflection) until the auto-reflection target can be observed through the telescope.

f. With the lower horizontal tangent screw of the auto-reflection angle mirror, rotate the mirror until the vertical crosshair in the transit's telescope are perfectly superimposed (placed) between the vertical pair of proper dash marks (nearest the center) on the auto-reflection tar-


VERTICAL LINE OF SMALL CROSS
VERTICAL LINE OF THE TRANSIT TELESCOPE'S CROSS HAIR

BUCK-IN THE AUTO-REFLECTION ANGLE MIRROR UNTIL THE VERTICAL LINE OF THE MIRROR'S SMALL CROSS COINCIDES PERFECTLY WITH THE VERTICAL LINE OF THE TRANSIT TELESCOPE'S CROSS HAIR

Figure 43. Bucking-in mirror.

get, as illustrated in figure 44. NOTE: *If the horizontal crosshair in the transit's telescope is not centered between the proper (nearest the center) horizontal dash mark of the auto-reflection target, adjust the two opposite leveling screws (of the auto-reflection mirror) that are parallel to the line of sight until the telescope's horizontal crosshair is perfectly superimposed (placed) on the auto-reflection target. When this has been accomplished, the auto-reflection angle mirror can be considered perpendicular to the transit's line of sight and auto-reflection has been established.*

13. Tilting Dumpy Level

13-1. The tilitng dumpy level, illustrated in figure 45, is a type of sight level having a 30-power (30X) terrestrial telescope with a minimum focus of 5 feet. It is discussed separately here because of its peculiar importance. When used with the optical micrometer as an attachment, the instrument will maintain an accuracy of ±0.003-inch at 20 feet and ±0.010-inch at 60 feet. Along with the accuracy, we will include discussion on nomenclature and setting up the instrument.

13-2. **Advantage and Operation.** The outstanding advantage of the tilting level is that with it, the telescope is pivoted about a horizontal axis which intersects the vertical axis of the instrument. Because of this, when you use this level, the height of the telescope axle above the ground does not change as the telescope is rotated, even if the center spindle is not vertical. Since the height of the telescope axle is not fixed and does not change when the telescope is precisely leveled, the horizontal plane swept by the precisely leveled line of sight is always the same distance above the ground. Figure 45 shows both the side views of the tilting dumpy level.

13-3. **Nomenclature.** You must learn the name (as shown in fig. 45) and function of each part of this instrument before you can become skilled in its use.

13-4. *Clamp screw.* The clamp screw is used to lock the telescope in any position when the clamp's screw is tightened. When this screw is released, the telescope can be rotated in either direction about the vertical axis of the instrument.

13-5. *Tangent screw.* This is a fine-adjustment screw for rotating the telescope clockwise or counterclockwise about the vertical axis of the instrument after the clamp screw is tightened. By using this fine adjustment, the vertical crosshair of the instrument can be lined up with the target.

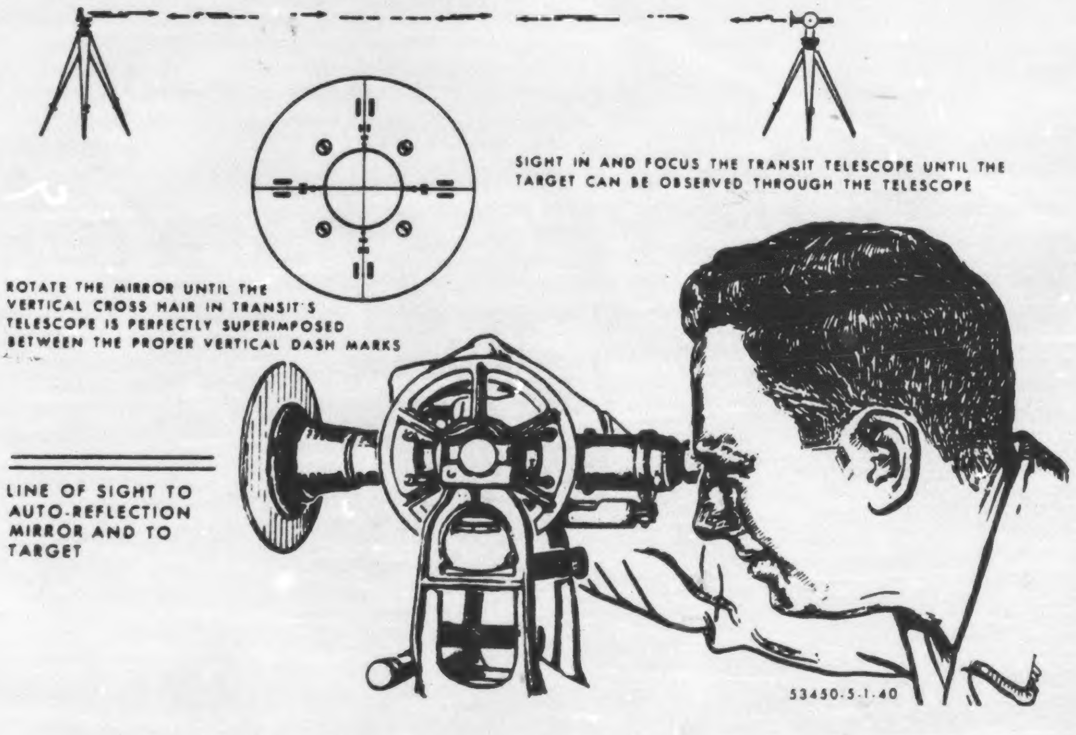

SIGHT IN AND FOCUS THE TRANSIT TELESCOPE UNTIL THE TARGET CAN BE OBSERVED THROUGH THE TELESCOPE
ROTATE THE MIRROR UNTIL THE VERTICAL CROSS HAIR IN TRANSIT'S TELESCOPE IS PERFECTLY SUPERIMPOSED BETWEEN THE PROPER VERTICAL DASH MARKS
LINE OF SIGHT TO AUTO-REFLECTION MIRROR AND TO TARGET
53450-5-1-40

Figure 44. Establishing auto-reflection.

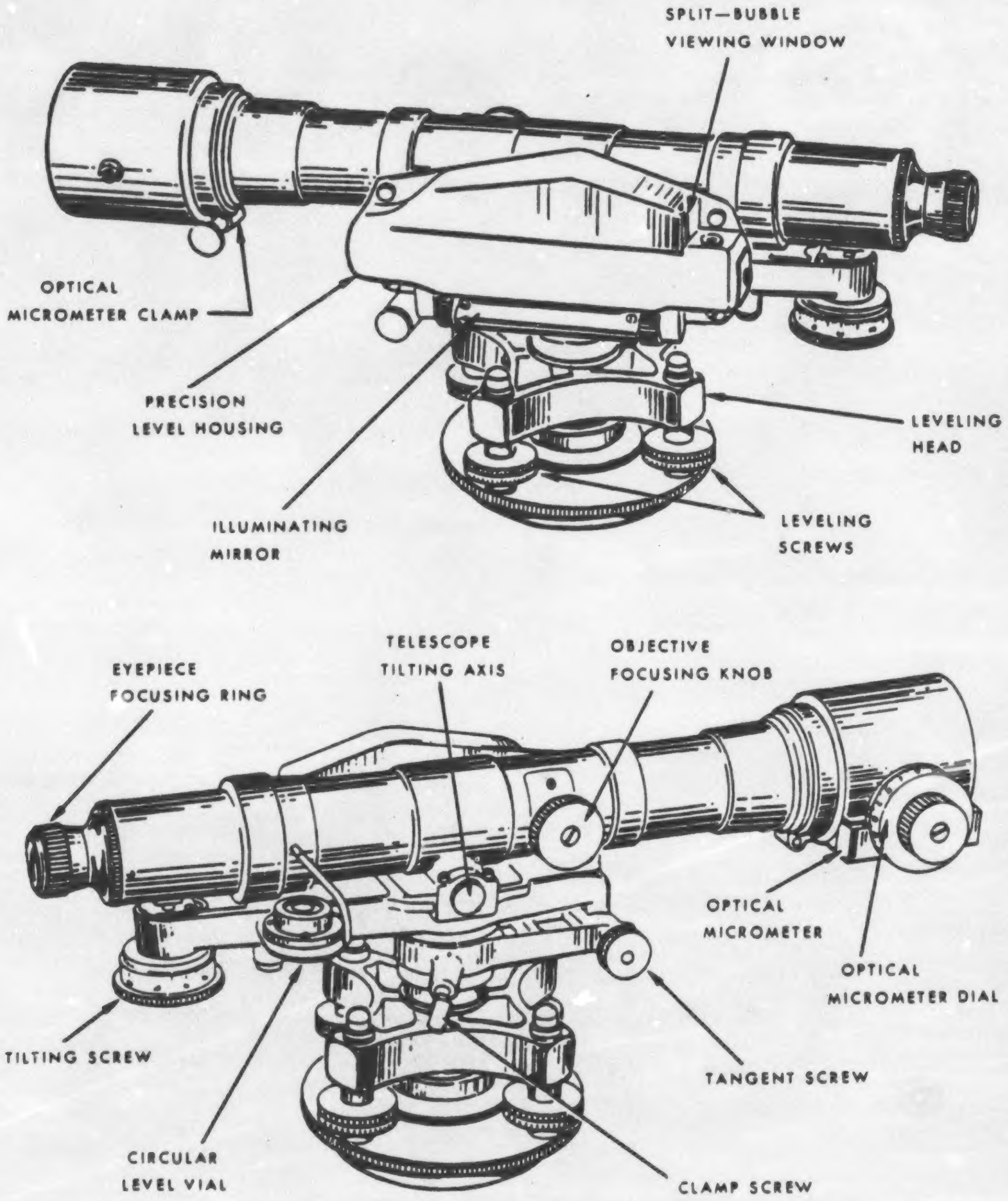

SPLIT—BUBBLE
VIEWING WINDOW
OPTICAL
MICROMETER CLAMP
PRECISION
LEVEL HOUSING
LEVELING
HEAD
ILLUMINATING
MIRROR
LEVELING
SCREWS
TELESCOPE
TILTING AXIS
EYEPIECE
FOCUSING RING
OBJECTIVE
FOCUSING KNOB
OPTICAL
MICROMETER
OPTICAL
MICROMETER DIAL
TILTING SCREW
TANGENT SCREW
CIRCULAR
LEVEL VIAL
CLAMP SCREW
53450—5—1—41

Figure 45. Tilting dumpy level.

13-6. *Eyepiece focusing ring*. The purpose of the focusing ring is to compensate for variations in eyesight of different observers, enabling each observer to bring the crosshairs of the instrument into focus.

13-7. *Objective focusing knob*. This focusing knob is used to bring the image of the target into focus on the plane of the crosshairs as observed through the eyepiece. It is rotated to compensate for variations in distance between the telescopes and the various targets observed.

13-8. *Leveling screw*. Leveling screws are used to plumb the vertical axis. Some tilting levels are equipped with three leveling screws; some, with four.

13-9. *Circular level vial*. The circular level vial bubble can be centered by adjusting the leveling screws to plumb the vertical axis of the instrument.

13-10. *Tilting screw*. The tilting screw is used to raise or lower the eyepiece end of the telescope as necessary to center the level bubble. It is used for making minor adjustments each time a reading is taken.

13-11. *Split bubble*. The split bubble is a telescope precision level vial viewed through a series of prisms mounted inside the instrument. The bubble is observed through an eyepiece or viewing window and is illuminated by a mirror which can be adjusted by turning the attached knob. A white surface on the reverse side of the mirror is used to prevent glare when an excessive amount of light is present.

13-12. Because the tilting dumpy level and the optical micrometer are used together, we will discuss their setup, adjustment, and use together after discussing the optical mircometer instead of examining the setup, adjustment, and use of each separately.

14. Optical Micrometer

14-1. All optical mircometers are attachments for levels and transits that are used for very precise leveling and alignment. With the use of optical micrometers, measurements can be made up to 0.001-inch.

14-2. Used with sight levels, optical micrometers displace the line of sight from the horizontal plane of the instrument vertically (up and down). In contrast, those used with transits displace the line of sight from the vertical plane of the instrument horizontally (left to right).

14-3. The optical micrometer, as shown in figure 46, consists of a disc of optical glass with flat parallel faces called *plano-parallels*, or *optical flat plates*. The micrometer is arranged so that the glass can be precisely tilted by the movement of the graduated drum. The device is mounted on the instrument instead of the sunshade so that the plate is in front of the objective lens.

14-4. The condition necessary to establish a reference line of sight is that the optical micrometer drum initially be set at zero. The sights are taken on a steel scale graduated in eighths of an inch. The drum is then turned so that the line of sight and the definite scale graduation are indicated in thousandths of an inch on the calibrated mircometer drum. This distance, as shown in figure 47, is added or subtracted from the scale dimension to obtain the distance from the end of the scale to the line of sight. The range of displacement is 0.100-inch up or down. Using this attachment in the manner explained will insure precise readings, whether the scale is up or down, left or right.

14-5. The sequences necessary for the proper setup, adjustment, and use of both the tilting dumpy level and the optical micrometer are outlined together below because, as we have said earlier, they are used together. Those sequences are as follows:

- Readying the tripod.
- Installing the tilting dumpy level.
- Attaching the optical micrometer.
- Rough-leveling the instrument.
- Checking the height of the instrument.
- Precision-leveling the tilting dumpy level.
- Using the optical micrometer.

14-6. The details involved in each of these steps are important enough to the airframe repair specialist for us to consider each of them separately, though still in the sequence listed here.

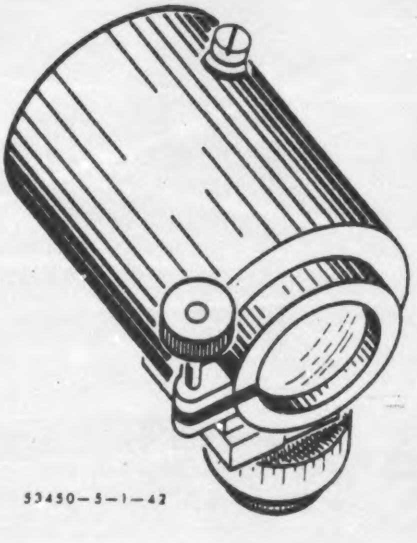


Figure 46. Optical micrometer.

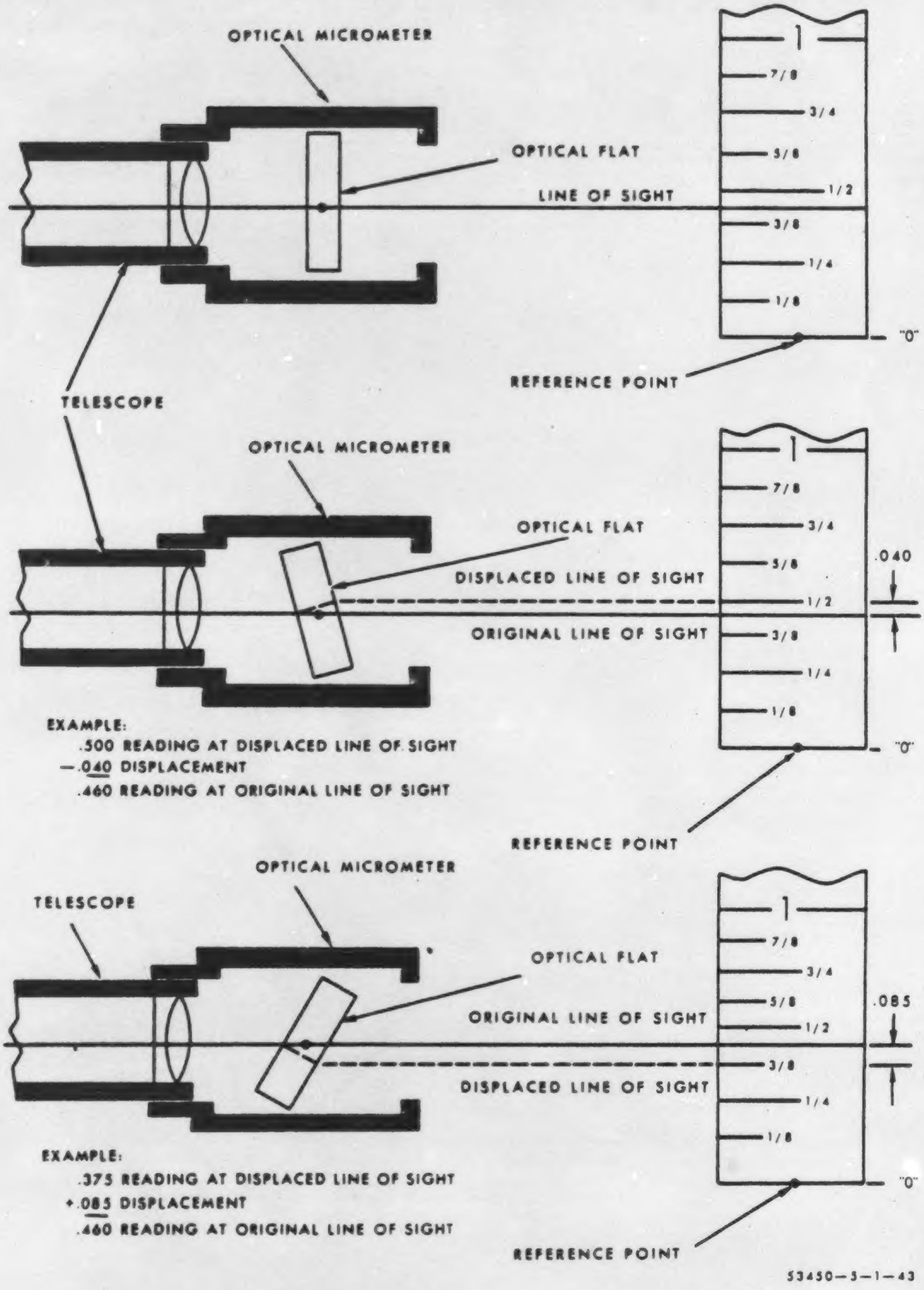

OPTICAL MICROMETER
OPTICAL FLAT
LINE OF SIGHT
TELESCOPE
REFERENCE POINT
1
7/8
3/4
5/8
1/2
3/8
1/4
1/8
"0"
OPTICAL MICROMETER
OPTICAL FLAT
DISPLACED LINE OF SIGHT
ORIGINAL LINE OF SIGHT
.040
EXAMPLE:
.500 READING AT DISPLACED LINE OF SIGHT
—.040 DISPLACEMENT
.460 READING AT ORIGINAL LINE OF SIGHT
REFERENCE POINT
OPTICAL MICROMETER
TELESCOPE
OPTICAL FLAT
ORIGINAL LINE OF SIGHT
DISPLACED LINE OF SIGHT
.085
EXAMPLE:
.375 READING AT DISPLACED LINE OF SIGHT
+.085 DISPLACEMENT
.460 READING AT ORIGINAL LINE OF SIGHT
REFERENCE POINT
53450—3—1—43

Figure 47. Reading dimensions to line of sight.

585

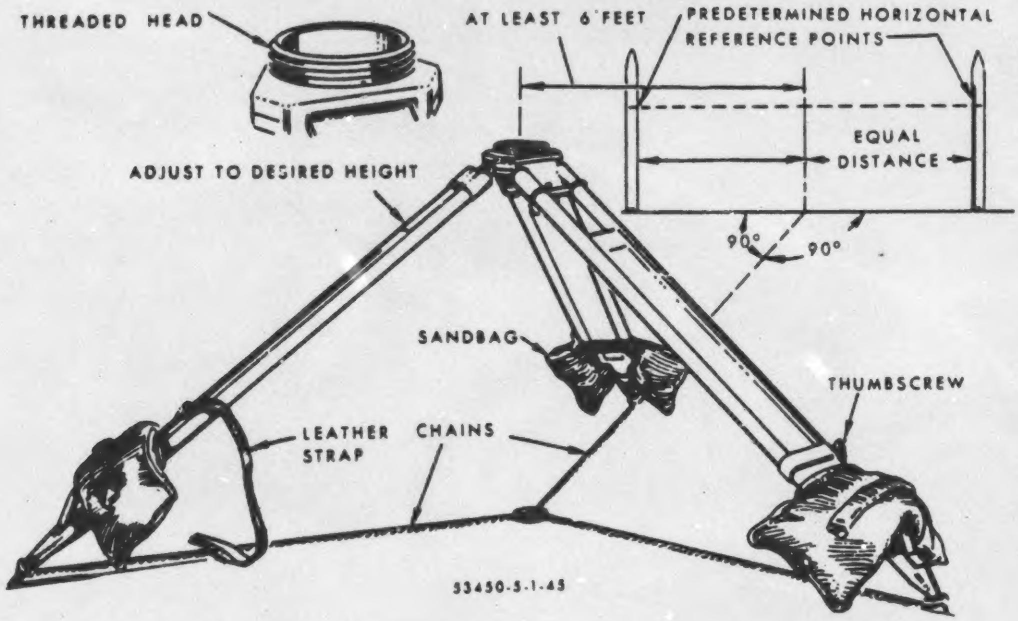

THREADED HEAD
AT LEAST 6 FEET
PREDETERMINED HORIZONTAL REFERENCE POINTS
EQUAL DISTANCE
ADJUST TO DESIRED HEIGHT
90°
90°
SANDBAG
THUMBSCREW
LEATHER STRAP
CHAINS
53450-5-1-45

Figure 48. Tripod setup.

14-7. **Readying the Tripod.** To do this, set up, adjust, and position the tripod as follows:

a. Loosen the leather strap and thumbscrews.

b. Set up the tripod on an improvised tripod stabilizer (baseplate or chains and sandbags), as shown in figure 48.

c. Adjust the tripod to the desired height, locking it into place with the thumbscrews, and remove its cover.

d. Position the tripod and improvised tripod stabilizer approximately an equal distance from the predetermined horizontal reference points. Maintain a minimum local distance of at least 6 feet between the predetermined horizontal reference points and the tripod.

14-8. **Installing the Tilting Dumpy Level.** Install the tilting dumpy level on the threaded head of the tripod as follows:

a. Open the cover of the carrying case and release the clamp screw on the instrument.

b. With one hand firmly grasping the framework, support the telescope, as shown in figure 49, and lift it carefully from its carrying case. NOTE: *You should always grasp the framework supporting the telescope on the opposite side of the precision level housing. We recommend this procedure, because any time a hand is placed on the precision level housing, the heat of that hand will cause the spit bubble within the vial to become erratic (i.e., wander). When the spit bubble becomes erratic for any reason, it is impossible for anyone to make any immediate adjustments which are accurate. Also, if the instrument is grasped on the side of the precision level housing, the pressure of the hand or thumb on its mount will cause it to be thrown out of adjustment with the telescope tube.*

c. Lift the instrument high enough to clear its carrying case, place your other hand under the instrument for support, and carry the instrument to the tripod setup.

d. Place the instrument's threaded base squarely on the threaded head of the tripod.

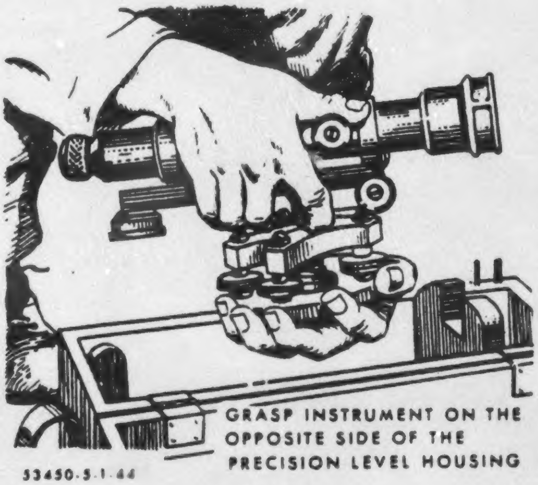

GRASP INSTRUMENT ON THE OPPOSITE SIDE OF THE PRECISION LEVEL HOUSING
53450-5-1-44

Figure 49. Lifting level.

e. Maintain a firm grip on the framework opposite the precision level housing with one hand, as shown in figure 50, while you use your other hand to start the threads by rotating the threaded base of the instrument counterclockwise until you hear a click, one indicating that the threads have meshed.

f. Finally, turn the threaded base of the instrument clockwise until it is seated snugly to the threaded head of the tripod.

14-9. **Attaching the Optical Micrometer.** Attach the optical micrometer on the telescope of the tilting dumpy level as follows:

a. Remove the optical micrometer from its carrying case and loosen the micrometer clamp.

b. Attach the optical micrometer, as shown in figure 51, to the front of the telescope, with the optical micrometer dial facing the right of the telescope and the optical micrometer clamp on the bottom side.

c. Tighten the optical micrometer clamp screw snugly.

14-10. **Rough-Leveling the Instrument.** Rough-level the instrument as follows:

a. Set the tilting screw, as shown in figure 52, to the zero reading on its drum.

b. Check and tighten the leveling screws snugly to secure the instrument in place. As you do this, you must tighten the leveling screws to a proper tension. Why? Because, as we have said earlier, leveling screws that are too tight cause creeping and damage to the instrument.

c. Loosen the clamp screw and position the telescope parallel to one set of opposite leveling screws.

d. Tighten the clamp screw to secure the instrument in place.

e. Center the bubble within the circular level vial as nearly as possible by adjusting the pair of opposite leveling screws parallel to the telescope. The two opposite leveling screws, shown in figure 53, are always turned at the same time in opposite direction to each other. The travel of the bubble within the circular level vial is controlled by the direction in which the leveling screw is turned by the left thumb. From the eyepiece end of the telescope you can see the bubble within the circular level vial by looking at the mirror which is attached directly over the circular level vial.

f. Next, adjust the set of opposite leveling screws (the screws that are perpendicular to the telescope) until the bubble is centered with the circular level vial.

g. If necessary, repeat the two preceeding steps until the bubble is centered within the bull's-eye of the circular level vial. When you have accomplished this, you can consider the instrument rough-leveled.

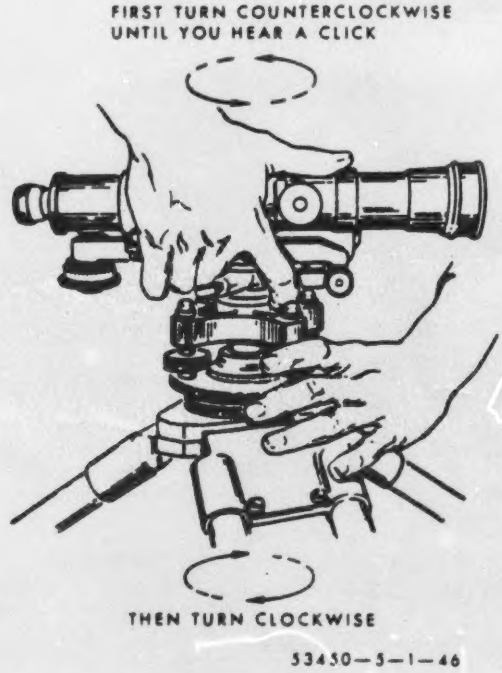


Figure 50. Installing level on tripod.

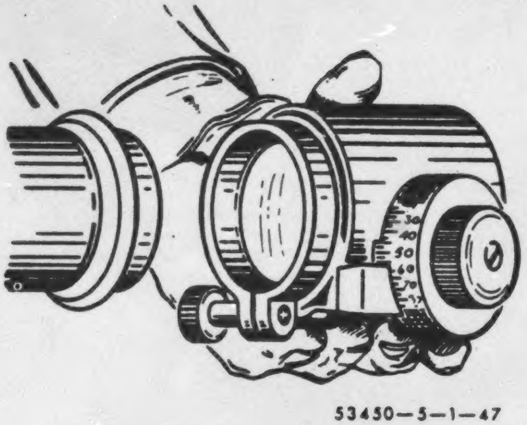


Figure 51. Optical micrometer installations.

14-11. **Checking the Height of the Instrument.** Check the height of the instrument as follows:

a. Set up targets at the predetermined reference points, using graduated scales as targets.

b. Sight-in the targets to make sure that the instrument is properly positioned.

c. Adjust the eyepiece focusing ring until the crosshairs are sharp and clear.

d. Adjust the objective focusing knob to bring the image (target) into the plane of the crosshairs.

e. Check for and eliminate parallax.

f. If the height adjustment is necessary, remove the instrument from the tripod setup as follows:

(1) Remove the optical micrometer from the telescope and place it in it's carrying case.

(2) Loosen the clamp screw.

(3) With one hand firmly grasping the framework opposite the precision-level housing, unscrew the instrument from the tripod's threaded head by turning the instrument's threaded base counterclockwise with your other hand.

(4) Use one hand to lift the instrument clear of the tripod setup, then place your other hand under the instrument for support and carry it to its carrying case.

(5) Make the necessary height adjustments to the tripod setup.

(6) After making these adjustments, reinstall the instrument on the tripod setup in the manner already described.

(7) Reinstall the optical micrometer on the telescope.

(8) Reaccomplish rough-leveling.

14-12. **Tilting Dumpy Level Precision Leveling.** Precision-level the tilting dumpy level as follows:

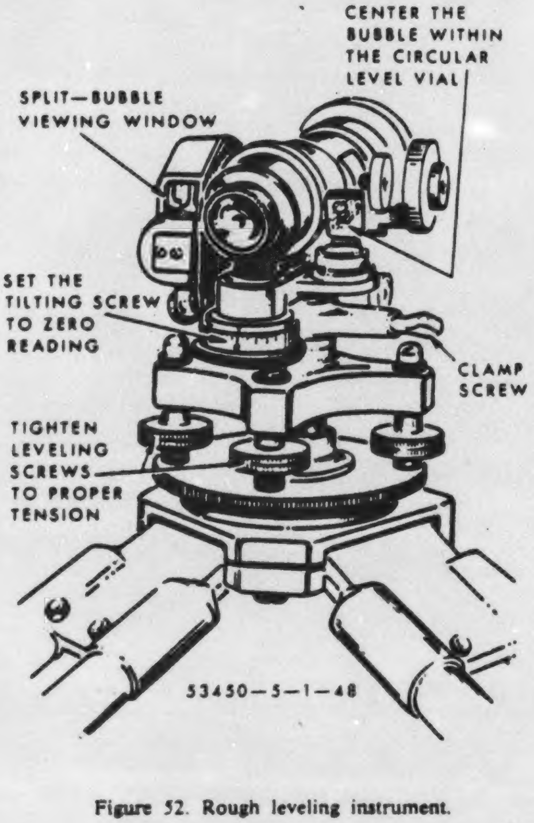

CENTER THE BUBBLE WITHIN THE CIRCULAR LEVEL VIAL
SPLIT—BUBBLE VIEWING WINDOW
SET THE TILTING SCREW TO ZERO READING
CLAMP SCREW
TIGHTEN LEVELING SCREWS TO PROPER TENSION
53450—5—1—48

Figure 52. Rough leveling instrument.

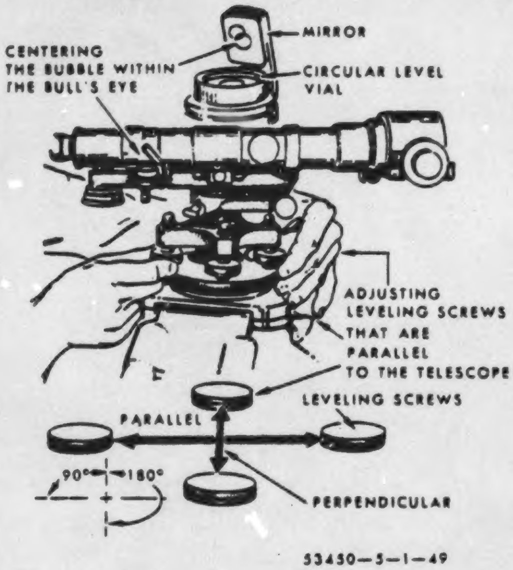

CENTERING THE BUBBLE WITHIN THE BULL'S EYE
MIRROR
CIRCULAR LEVEL VIAL
ADJUSTING LEVELING SCREWS THAT ARE PARALLEL TO THE TELESCOPE
LEVELING SCREWS
PARALLEL
90°
180°
PERPENDICULAR
53450—5—1—49

Figure 53. Adjusting leveling screws.

a. Loosen the clamp screw and position the telescope parallel to one set of opposite leveling screws.

b. Tighten the clamp screw to secure the instrument in place.

c. Check and zero-in the tilting screw on its drum, if necessary.

d. Bring the split bubble within the precision-level vial into coincidence by adjusting the proper pair of leveling screws. Bring the split bubble within the precision-level vial into coincidence by adjusting the leveling screws that are parallel to the precision-level housing. The two ends of the split bubble may appear as shown in windows numbers 1 and 2 of figure 54 before proper adjustment. After making the proper adjustment, you will find the ends of the split bubble in coincidence (aligned), as shown in window number 3 of figure 54.

e. Loosen the clamp screw, rotate the telescope 180° about the instrument's vertical axis, and tighten the clamp screw to secure the instrument in position.

f. Take the reading on the tilting screw drum, shown in figure 55, and note the number of graduations moved away from the zero reading to correct coincidence error of the split bubble.

g. Turn the tilting screw one-half of the error towards the zero reading on the drum.

h. With the instrument in this position, bring the split bubble into coincidence by adjusting the leveling screws that are parallel to the precision-level housing.

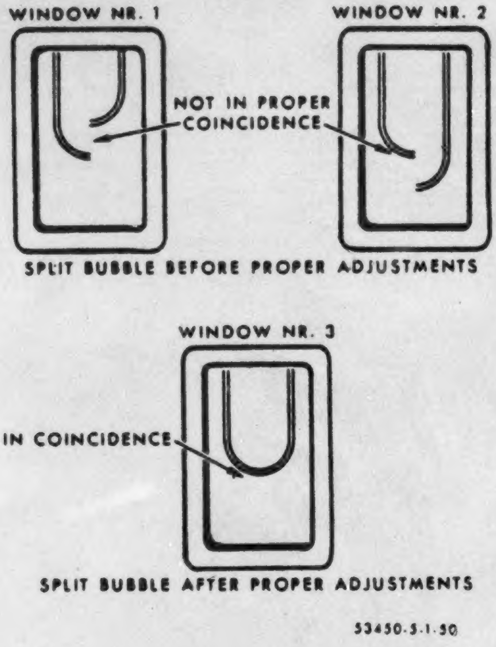

WINDOW NR. 1
WINDOW NR. 2
NOT IN PROPER COINCIDENCE
SPLIT BUBBLE BEFORE PROPER ADJUSTMENTS
WINDOW NR. 3
IN COINCIDENCE
SPLIT BUBBLE AFTER PROPER ADJUSTMENTS
53450-5-1-50

Figure 54. Improper and proper split bubble adjustment.

i. Loosen the clamp screw, rotate the telescope 180° to its initial position, and tighten the clamp screw to secure the instrument.

j. Check the coincidence of the split bubble within the precision-level vial. At this point, the split bubble should be in coincidence.

k. Loosen the clamp screw, rotate the telescope 90° about it's vertical axis, secure the telescope in position by tightening the clamp screw.

l. In this position, bring the split bubble within the precision-level vial into coincidence by adjusting the leveling screws parallel to the precision-level housing only.

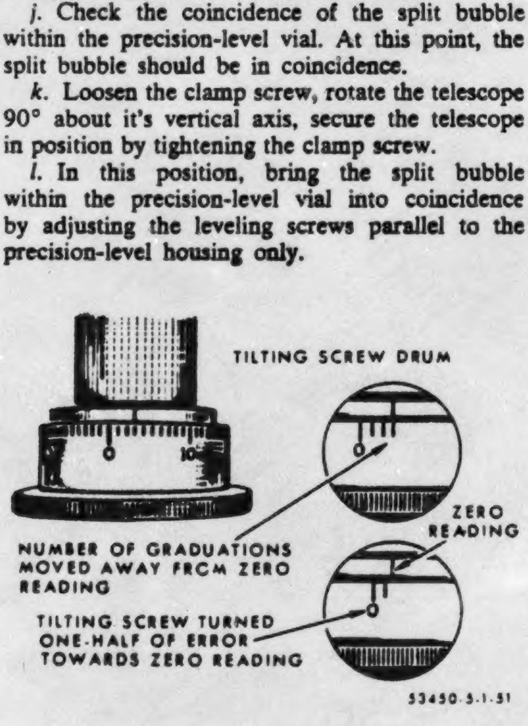

TILTING SCREW DRUM
0
10
ZERO READING
NUMBER OF GRADUATIONS MOVED AWAY FROM ZERO READING
TILTING SCREW TURNED ONE-HALF OF ERROR TOWARDS ZERO READING
53450-5-1-51

Figure 55. Adjustment for split bubble.

m. Loosen the clamp screw, rotate the telescope 180° about the instrument's vertical axis, and tighten the clamp screw to secure the instrument.

n. In this position, if the split bubble within the precision level vial is more than ¼-inch out of coincidence, correct one-half the error by adjusting the leveling screws parallel to the precision level housing.

o. Check the instrument for precision level at each quarter (90°) turn over the leveling screws. NOTE: *If the split bubble is still within a ¼-inch allowable coincidence tolerance, you can consider the instrument to be precision level. If the split bubble is not within the allowable ¼-inch coincidence tolerance, you must repeat the last 11 steps until the allowable coincidence tolerance has been accomplished.*

p. Finally, sight-in the targets (graduated scales) at the reference points. From this point on, or whenever the instrument is used for sighting-in, taking readings, establishing reference points, etc., it will be necessary to adjust the eyepiece focusing ring until the crosshairs are sharp and clear, the objective focusing knob is adjusted to bring the image (target) into the plane of the crosshairs, the telescope's line of

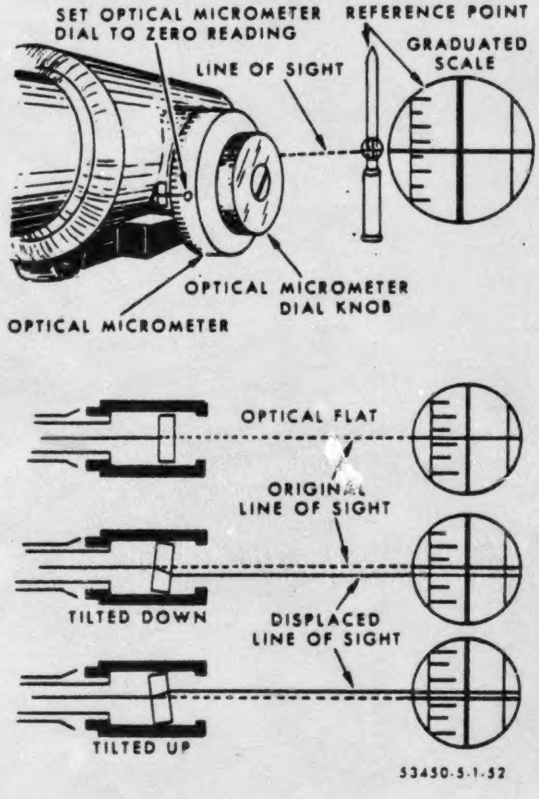

SET OPTICAL MICROMETER DIAL TO ZERO READING
REFERENCE POINT
GRADUATED SCALE
LINE OF SIGHT
OPTICAL MICROMETER DIAL KNOB
OPTICAL MICROMETER
OPTICAL FLAT
ORIGINAL LINE OF SIGHT
TILTED DOWN
DISPLACED LINE OF SIGHT
TILTED UP
53450-5-1-52

Figure 56. Optical micrometer readings.

sight is brought dead on the target with the tangent screw, the split bubble within the precision-level vial is brought into coincidence with the tilting screw, and parallax has been checked for and eliminated.

14-13. **Using the Optical Micrometer.** Taking a precise target (graduated scale) reading of dimensions, to a line of sight, by the use of an optical micrometer is accomplished as follows:

a. Set the optical micrometer dial to the zero reading on its drum by rotating the optical micrometer dial knob, as shown in figure 56.

b. Sight-in on the graduated scale along the original line of sight, also shown in figure 56.

c. Using the optical micrometer dial knob, rotate the optical flat until the horizontal crosshairs of the telescope are in perfect coincidence with the nearest ⅛-inch scale graduation. The distance between the original line of sight and the definite scale graduation is indicated in thousandths of an inch on the optical micrometer dial drum. This distance is added or subtracted from the scale dimension to obtain the distance from the end of the scale (reference point) to the line of sight, as shown in figure 56. NOTE: *It is not our intention in this course to elaborate on the actual alignment by optical equipment of any particular aircraft. When you are required to perform these inspections, the applicable –2 and/or –3 technical manuals for the particular aircraft involved must be used to define the locations and station numbers needed. These technical manuals show where your equipment is to be placed and where the plumb lines must be located to accurately check the alignment of the aircraft.*

CHAPTER 3

Personnel Management

TO MOST OF US it is a wonderful feeling to realize we have been selected to perform assistant supervisory duties. Most of us like some of the feelings that go with a higher position—added prestige, power over others, and our own progress. We are pleased that management has recognized our potential ability. Perhaps you have thought of supervision as an easy job when you observed supervisors giving orders and letting others do the hard work. You may think of them as setting comfortably at desks, watching men work, chatting leisurely with others, going to various meetings, and enjoying special privileges. You probably have thought: "That's for me!" Well, this is your opportunity to sample some of these experiences; however, without study, training, and experience, your future as a supervisor may not be so wonderful.

2. Let's briefly think about some of the situation that can develop if you do not have adequate supervisory preparation. As a supervisor, from the first day on you will be confronted with many problems and situations requiring immediate action. These troubles multiply at an alarming rate, and you may wish that you were back at the old job, where life was pretty simple after all. Right from the start, a wrong decision, a careless remark, or a violation of a human relations principle may take months to straighten out. You suddenly become aware of the fact that you are up against more than you bargained for! This job of supervision is not as easy as it looked!

3. Some people cannot take this new responsibility. They find it too bewildering, too demanding, too uncomfortable. These people often request to be returned to their old jobs, where they were responsible only for their own output, where someone else told them exactly what to do. Others go into the new job line like a "bull in a china shop," making one mistake after another, until management is forced to remove them from their new positions. Still others are too weak, too timid, too unintelligent, too immature, or too lacking in other factors of leadership required in supervisory positions. Generally they, too, fall by the wayside. But most of us somehow survive the shock, and eventually we learn to like the new work. Being a supervisor in a vital military establishment like the Air Force is a grave responsibility, but the rewards are great for those who can make the grade.

4. After you become a 53450 you will begin assuming supervisory duties. This chapter will discuss some of the responsibilities related to personnel management, such as the personality traits of a leader, promoting harmonious relationships, resolving personnel problems, and using performance requirements. The principles and procedures discussed is this chapter can be applied to various personnel management situations that you will encounter in the airframe repair shop and in other Air Force activities.

15. Promoting Harmonious Relationships and Resolving Personnel Problems

15-1. A leader is a person who leads, guides, directs, or commands the efforts of one or more people in getting jobs done. He is a supervisor and manager as well. Not only does he lay out the details of a job and assign and advise workers, but also, in many cases, he has to assemble equipment and materials. Further, he must account for the time of the workers and the material they use. You will find that effective management and leadership create a willing, cooperative, progressive, and continuously improving work force. These two important elements also develop a work force that is purposeful, skilled, trained, and smooth in operation.

15-2. **Personality Traits of a Leader.** Very few of us are leaders in all situations. Actually, most of us spend more time being led than leading. If you expect to accomplish a worthwhile job of supervision, you will start acquiring the traits that you most admire in leaders. We will start you off with the following list, which is by no means complete. We expect you to make additions to it.

a. Friendliness. Be friendly toward the people who work for you, yet retain their respect for your ability and leadership. Don't be noticeably more friendly toward some people than others.

b. Initiative. Have the ability and willingness to start new projects. Enjoy your work, and project your enthusiasm to others.

c. Ability to make decisions. Be able to make decisions based upon careful reasoning. Be able to admit it when you don't know an answer; however, don't pretent to know an answer when you don't.

d. Interest in people. Have an interest in people—be able to listen sympathetically to their problems and make an effort to understand them.

e. Understanding. Realize that a person may not be at his best at all times and that trouble at home or outside worries can effect anyone's efficiency. Understand that your men are individuals.

f. Sincerity. Don't simulate friendliness and interest. Don't be a "hypocrite." Make complimentary comments only when you really mean them. Identify yourself with your men to the point that you will fight for them, even in their absence, provided they are in the right.

g. Pride in accomplishment. Have a sincere desire to see your men do good work—not fear that they will become as proficient as yourself. You should want your men to succeed and be proud when they do. Don't be afraid of your position, your subordinates, tough jobs, or honest mistakes. Convey the impression that you are trying to work yourself out of a job and your men into it.

h. Patience and emotional control. Never assume that because a task is easy for you, it will also be easy for everyone else. Realize that the person to whom you must explain a task several times may later perform the job much better than the fast learner. Control your temper and think before you speak. A workman may hold a grudge a long time because of words spoken too hastily—and a worker with a grudge won't be as efficient. When necessary, give constructive ciricism without losing your temper. When things go wrong on the job, appear calm and unperturbed—and do not get frustrated. Straighten out problems with as little fuss as possible.

i. Fairness. Don't deal out favors to those who feed your ego. Establish fair production standards; don't require one man to complete a big job in the same time that you give another man to complete a smaller job. When you evaluate a man, rate him on actual performance (production and quality) rather than upon his friendly overtures to you.

j. Personality. Personality is not what you have; it is what you do when you are with others. Success will come only when you have entirely forgotten yourself and, instead, become sensitive to others. Learn the art of forgeting yourself in a group. It isn't difficult; simply watch the other fellow and do what is appropriate. Think of each person as being a distinct individual, one whom you will try to understand and make a bit more happy. Perhaps the best rule of action is the Golden Rule: *Do unto others as you would have them do unto you.*

15-3. **Basic Needs of People.** The fact that a worker may reach a satisfactory production level doesn't mean he is going to stay there without further attention. As you well know, many things cause a worker to "let down" in his performance. For apparently no reason, a worker may change overnight from a satisfactory, satisfied performer into an unhappy, low producer. One of the responsibilities of a supervisor is to find out what these reasons are and to help that worker on the way back to high performance. This is a difficult job, because there are no hard and fast rules that work for everyone. Workers aren't like machines. You can't just look at them and determine why they don't run right. Workers are people with ambitions that can be stirred, pride that can be hurt, nerves that can be shattered, and hopes that can be realized. This makes workers complex and difficult to understand, but you must understand them if you are to develop a satisfied, cooperative, and productive work force. To help you understand what makes people act as they do, it is necessary for you to know the basic needs of people: recognition, opportunity, security, and a feeling of belonging.

15-4. *Recognition.* Every person has a basic need that we call *recognition.* Each person has his own way of expressing this need; but nevertheless, it exists in all of us. For instance, you might think about some of the things that have happened to you that made you feel you were being recognized: (1) receiving credit for what you did and praise for a job well done; (2) being given the feeling, by attitude and actions of your supervisor, that what you did was important and contributed to the success of your organization; (3) being allowed and encouraged to express your opinions in matters that affected you; (4) receiving adequate pay for work done; and (5) receiving the respect of your associates. Again, you might ask yourself these questions: "Are these things important to me? Do I need to be satisfied and content in my job?" If your answer is "Yes" to either question—and almost everybody gives this answer—then recognition is one of your basic needs. But, as a supervisor, you need to understand that other people need recognition too; so when you are supervising a man, tell him how he is doing, give him a pat on the back, keep him informed, give him special assignments, and when the time comes, consider him for promotion.

15-5. *Opportunity. Opportunity* is another one of our basic needs. The desire to improve our position and station is an important part of our job situation, but there are other types of opportunities which are important to workers, such as the opportunity to do a good job, the opportunity for greater professional development on the job, and the opportunity to use their best abilities so far as such use is consistent with requirements.

15-6. *Security.* This is another basic need that workers must satisfy if they are to be content and adjusted to their job situation. We're not talking about *security* as the term used in relation to safeguarding military information. No, the kind of security we're talking about is the feeling that your superior trusts you to do a good job without looking over your shoulder all of the time as well as the feeling that you can keep your job as long as you do it well. In general, we're talking about having a sense of well-being and satisfaction about your job, your family, your associates, and your friends. Just as in the case of the other basic needs, security doesn't mean the same thing to every person. Each of us has a somewhat different idea of security. To some, it is money in the bank; to others, it is a happy and secure home life; and to still others, it is a permanent job. Although security doesn't have the same meaning for everyone, each individual strives to attain the kind of security he needs.

15-7. *Belonging.* People are essentially social by nature. The entire history of mankind is made up of stories about people banding together for some common cause. Just driving into any medium-size town will provide an example of this. Somewhere on the way into town you will probably find signs announcing the day of the meeting and the location of all sorts of civic and service clubs, such as the Rotary, Kiwanis, and the Lions clubs. None of these would exist if it weren't for the desire of men to *belong* to groups and to be identified with them. This desire to belong also exists among personnel in offices and workshops where there are a number of people. Looking further into a group of working people, we find informal groups or organizations. The informal organization develops out of common interests, likes, dislikes, and sentiments of people. People who enjoy the same sort of activities are usually drawn together because of the interest they share in these activities.

15-8. A supervisor must recognize that an informal organization exerts a very powerful influence over the productivity of his unit. Through the threat of losing status in the group, a worker can be influenced to adjust his production (either upward or downward). His attitude toward the "boss" can be affected—he doesn't dare to be friendly if the group he belongs to is hostile. In other words, whatever conduct any particular group considers appropriate is the type of conduct you can expect from each member of that group. Consequently, the wise supervisor learns to recognize the leaders of such informal groups and to work through them; or even better, he is able to relate himself to the group and—through his leadership abilities—to become leader of the informal group as well as leader in the shop (formal) organization. In any event, the challenge to the supervisor is that he must find a way to convince the informal organization that its needs can be met by achieving the goals of the formal organization.

15-9. **Individual Differences.** Although all of the basic needs we have just discussed are common to everyone, they are not present to the same degree in each individual. Whereas some workers desire recognition above security, others want security more than anything else. For example, a young man just out of school may be more interested in opportunity for advancement than in security. An older worker with several children and a mortgage on the house will probably be more interested in security.

15-10. There are all sorts of differences in people: attitudes, abilities, aptitudes, interests, experience, emotions, education, religion, age, knowledge, skill, physical strength, and many others. What do these differences mean to you as a supervisor? Many things, but a few of them are as follows: They have a bearing on assignments; they have a bearing on the worker's stability; and they have a bearing on the way the worker acts and reacts.

15-11. The feelings of individuals are more often conditioned by emotion than by fact or logic. A supervisor cannot change the emotional nature of a worker, but through study of the individual and the situation, he can learn how to help the worker adjust to a situation. Just as the basic needs of people seem to fall into four basic categories, the differences among them also seem to fall into four different groupings: mental, emotional, physical, and social. The last named, while it does partially overlap each of the first three, is listed separately because of its peculiar importance.

15-12. Individual differences can affect the way you assign your work. If, for example, the work you want done requires heavy lifting, you would look for workers who are physically strong. If, on the other hand, the work involves much high pressure, you would try to get people who are emotionally stable. Again, you wouldn't assign a person to a pattern development project, if he was new and had very little experience in pattern development. Also, you usually try to take advantage of a person's formal education when it related to the type of work he is doing. Here again we could go on and on, but there examples illustrate the importance of considering individual differences when assigning work to people or considering people for job assignments.

15-13. We have mentioned how individual differences are important in making assignments and dealing with workers to satisfy their basic needs. The supervisor, then, has to work differently with each individual if a good job atmosphere is to be established. Thus, while dealing with workers resolves itself into recognizing and satisfying their job wants, it is not a simple task. Workers don't come to the supervisor and say "I want recognition," or "I want security," or "I want to be a part of the group." Rather, they reveal by their attitudes, emotions, and actions that these basic urges or desires are motivating them. They usually do this in a manner peculiar to their individual makeup, and the indications are varied and sometimes violent. When desires become thwarted, reactions result which should signal to the superior that something is wrong.

15-14. The supervisor must know his workers and their individual desires well enough to help them get job satisfaction. This is the key to good human relations. To guide worker actions, a supervisor must know enough about his people to be able to determine the approach he should use to get positive reactions. Good human relations are based upon friendly contact and understanding. An objective and orderly study of people and their actions is needed. It requires building techniques for dealing with people in terms of these understandings.

15-15. **Techniques of Good Human Relations.** We have seen that the basic needs we discussed —recognition, opportunity, security, and a feeling of belonging—are felt to a certain degree by all people. On this basis, we can therefore make a generalization to the effect that all people are alike. Yet we also found that people have definite physical, mental, emotional, and social differences. Again, we can generalize and say that no two people are alike. Taken separately, these statements about basic needs and individual differences seem to be true; yet when we put them together, they obviously contradict each other. What's wrong here?

15-16. Let's assume that both of the statements are true. Perhaps if we take them one at a time, we can arrive at some conclusions about people that will help a supervisor who is trying to establish good human relations among his workers. Examine the first statement, "People are alike." If this is true, we can see the possibility of the supervisor's developing certain techniques in dealing with workers—techniques which will apply to people in general and will assist him in his efforts to help his workers adjust to their jobs and form an integrated, cooperative work force.

15-17. *Let each worker know where he stands.* All workers need to know they are getting along well, if they are to be happy and satisfied with their jobs. This includes whether they are doing a good job or not. How can we do this? We can take an interest in our workers and get to know each one personally. We can have periodic talks with each worker and see that each knows his job requirements. How often you contact your workers and how close the personal relationship should be will depend upon your individual work situations. There is a delicate balance between overfamiliarity and friendship. As a supervisor, you must walk the fine line of propriety or risk severe criticism, which can be very damaging to morale and productive output in your unit.

15-18. *Give credit when due.* This is another technique to guide the supervisor in his job relations with his workers. We know this is a good one. Experience has proven that this technique will get good results, and we know that the supervisor who ignores it will create problems that will cause lagging interest among the workers. But knowing the technique and knowing how to put it to use are two different things. Give credit when due is a good idea—but how do you do it? There are many ways. Here are some of them: (1) Give a fellow a pat on the back and a little praise when he does a good job; (2) use letters of appreciation and commendation; (3) recommend outstanding performance ratings; (4) use both the military and civilian suggestion programs which may give cash awards and other rewards for improvements developed by your people; and finally, (5) do not overlook the very important method of recommending personnel for promotion, upgrading, and better assignments.

15-19. *Inform workers in advance and let them participate in planning.* Supervisors can inform their workers of changes by personal contact with each individual, by written notices and bulletins, or by informal meetings and discussions. The latter is a good method, but just calling workers together in a meeting does not automatically win their support and approval of changes. The supervisor still has the problem of getting their interest and participation. He must do something to make the workers want to take part in planning for changes. He must encourage them to contribute their ideas and "pitch in" to meet the problems. It is the supervisor's attitude and conduct in general that make workers willing to cooperate.

15-20. *Gain the workers' confidence.* Some ways to achieve this are to take a personal interest in each worker; to be friendly, helpful, and fair in your dealings; to encourage the worker to come to you with his problems; and to take actions on the problems if at all possible.

15-21. We have discussed ways of putting human relations techniques into practice. These are by no means all of the techniques that a supervisor will use. However, those discussed are of major importance and, when used properly, will be of great assistance to a supervisor.

15-22. Although techniques are useful in dealing with people, they will fail if they are not used properly. Supervisors may know theories of handling people, but when it comes to dealing with individuals, more specific knowledge is required. The supervisor must get to know his workers, and understand their particular difficulties and needs before he attempts to apply techniques. He must study the individual worker, learn his personal interest and problems, and know his reactions. It is just plain common sense that satisfied workers will perform better than unhappy workers. We repeat: Your chances of having satisfied workers are greatly increased when you:

- Let each worker know where he stands.
- Give credit when due.
- Keep workers informed.
- Encourage workers' participation.
- Gain workers' confidence.

15-23. These five techniques are essential in good human relations. The supervisor who develops. A supervisor who recognizes these techniques and applies them with an understanding of the individual needs of his workers is described as a worker-centered supervisor—the king of person who most often earns the title of *leader*. The opposite of this is the *driver*, who is concerned only with production and who makes no effort to understand his workers. The big mistake which this type of supervisor makes is that he fails to recognize the importance of the individual when getting the work out. There is no doubt that he will get results and get the job done—but only to the limits accepted as mimum.

15-24. The worker-centered supervisor thinks of people first, is willing to sit down and talk with his people, coaches them and tells them in advance of changes, and gets their ideas on changes. This type of supervision is almost always by far the greater producer. The exceptions to this are few and usually owe their success to some unusual factor, such as a work situation or personality. Motivation can be both negative (fear) and positive (reward). The production-centered supervisor has a tendency to favor negative motivation; whereas the worker-centered supervisor favors positive. Various studies indicate that positive techniques more often achieve desired results than negative techniques as far as work output and job satisfaction are concerned. This is not to say that a good supervisor is concerned only with making people happy; it is conceivable that a person who carried this to extremes would never get anything done. He could give everybody 3 days off every week and never accomplish anything, but all of his workers would be happy in that respect. So the worker-centered supervisor is not one who forgets about the work to be done and just concerns himself with keeping people happy. Rather, he is one who relates the work to the individuals working under his supervision in a manner that wins their cooperation and support for the mission of the unit. A supervisor who builds good job relations can actually produce more than a supervisor who concentrates on production and attempts to drive his workers.

15-25. **Problem Solving.** Every day supervisors face problems that are new. If all of us were to go about solving problems in exactly the same manner, we would necessarily have the same thought processes. Although we do not think alike, all of those who are capable of finding proper solutions quickly and easily do have something in common. They follow a fairly well-established pattern of thought and action. There is no trick or magic formula for solving all problems, but those who are most successful follow an orderly, organized process, such as the following:

- Define the problem.
- Establish objectives.
- Gather facts.
- Weigh and decide.
- Take action.
- Evaluate action.

Let us look at each of these steps in a little more detail in order to fully understand how all six steps listed function as one unified and successful process.

15-26. *Define the problem.* This is the first step in problem solving. When trouble arises, we say that we have a problem. But if someone asks us, "Just what is your problem?" We often find it is difficult to put into words. Yet, if we cannot state the situation clearly, it is hard to know exactly what we want to accomplish. Defining our problem clearly leads us into setting objectives. For example a supervisor may be faced with what seems to be a problem of absenteeism. However, further study of the situation may reveal the real problem is transportation, housing, epidemic influenza, or even the world series. Again, a high percentage of spoiled work could represent a problem of forced machine speeds, poor materials, lack of training, or a number of less obvious reasons.

15-27. *Establish objectives.* To determine objectives, we need to know the whole story. We can do this only by securing as much information as is possible in the time available. It is poor management to risk a decision without sufficient facts. Granted, there are times when a decision must be made on the spur of the moment because of the pressure of time. But even then, every possible attempt must be made to get all of the information that should be known before the decision is made.

15-28. *Gather facts.* There are a number of sources from which information can be obtained. Some are records, rules, regulations, and customs that are applicable. Workers who are concerned with the problem may very well be better informed about it than the supervisor; it may be as important to get their opinions and feelings as it is to get the facts. The supervisor can gain information by listening to workers talk about the situation; keeping his eyes open and observing what is happening; reviewing records and policies; asking questions; and, if practicable, delegating the gathering of facts to an understudy.

15-29. One question that may seem puzzling is this: "How can a person tell when he has all the significant information or at least enough to solve the problem?" Perhaps the best guidance is to answer that as we consider the facts, they begin to fit together—to form a pattern. If the picture they form has missing pieces, it must be that some facts are missing. Maybe a second, closer scrutiny will uncover these additional facts. On the other hand, if the pieces, fitted together, add up to the answer, we need look no further. However, if you have some important facts left over that do not seem to fit in, maybe your diagnosis is wrong. Before you discard the facts as irrelevant, it is important that you really think about them. Sometimes important solutions, even new discoveries, are made by a person who can find the relationship between facts that others have passed over as unimportant.

15-30. *Weigh and decide.* What we have been saying is that, after we get the information, we have to fit the facts together and consider their bearing on each other. We can help clarify their relationship to each other by asking ourselves questions such as: What caused this to happen? Who was responsible there? Did this happen before or after that? Soon the facts will fit together like a jigsaw puzzle to form a clear picture. As you think about the problem and analyze the facts, possible solutions naturally will occur to you. You should list every reasonable solution for careful review later. As you do this, you will be most interested in checking the anticipated results of each possible action to determine the probable effect on individuals, groups, production, etc.

15-31. This process enables you to select the best action to take, because you will be able to identify that action which will best accomplish the purpose. You will remember that the purpose was stated in the objective. Other considerations of what action to take might relate to time, money, equipment, supplies, and other resources.

15-32. *Take action.* Up to this point, we have discussed ways to make a sound decision, but we cannot leave it here. All of the effort and time spent in arriving at this decision is wasted if favorable action does not result. A responsible official who delays or otherwise fails to take action which has been decided upon is avoiding his responsibility and may be showing a form of weakness. When taking final action on a problem, we have to consider these questions: Should I handle this myself? Do I need help in handling it? When and where should final action be taken?

15-33. *Evaluate action.* The best laid plans and the most carefully made decisions sometimes do not work out exactly as anticipated. Many times we just cannot get all the pertinent facts in the time available. Or it may be that some of the facts on which we based our judgment are false or misleading. Therefore, it is essential that we check on how the action is working out. Obviously, it is better to learn for ourselves that it is not working out and to make the correction ourselves than it is to wait for the boss to find out. We should be the first to know it, acknowledge it, and correct it. After all, we're only human, and we all make mistakes.

15-34. **Resolving Personal Problems.** There are workers with problems, and there are problem workers. Good supervisors are able to distinguish between the two. This ability is a fundamental requirement for effective supervision, because entirely different approaches are necessary to correct the two situations.

15-35. *Workers with problems.* Workers with problems may need assistance from the supervisor or from some other qualified person. Perhaps it is unfortunate that people are unable to keep their problems from affecting their work, but few can. Therefore, the more of their problems you resolve or help resolve, the less these problems will interfere with their work Such problems do not normally follow a particular pattern and therefore, each one must receive special attention.

15-36. *Problem workers.* The problem worker belongs to an entirely different category. This individual is one who fails to respond to efforts to help him; actually, he does not want help. He not only causes trouble for himself; but also, through his actions, or lack of action perhaps, he may disrupt others who are trying to do a good job. Corrective measures must be taken. A regulatory system has been established to assist you in handling severe cases.

15-37. One word of caution may be in order at this point. It is relatively simple for a supervisor to attempt to cover his own weakness by classifying as misfits anyone who objects to thoughtless misdirection. If the supervisor attempts to deal with them as he would a true misfit, he will encourage low morale and resentment.

15-38. It is fairly obvious that a good supervisor should deal firmly with problem workers; but at the same time, if the problems are to be solved, action could best be directed at causes rather than at people. Whenever you must deal with severe problems involving people, always ask yourself whether you are trying to fix the mistake or to fix the blame.

15-39. You have to recognize that some people will cause difficulties no matter how conscientiously you apply the various techniques of good human relations. But this does not mean that the application of these techniques is not worthwhile, because proper application will reduce the frequence and type of difficulties you encounter.

15-40. There may be problems you cannot solve without the help of your chief. There may be others you cannot solve without the help of some staff agency, such as the personnel office. However, you can, and should, try to solve problems within the scope of your authority without outside help if at all possible. Those beyond your authority must be referred, through formal channels, to higher authority for action. But by far the best procedure is for you to handle dissatisfactions before they get a chance to get into formal channels. In other words, you are concerned with how you can stop trouble in the early stages before it gets out of hand.

15-41. *Discussing problems.* Since a worker's problems are also the supervisor's problems, let's discuss how to handle them. You can use the systematic problem-solving techniques. When a worker shows symptoms of being in trouble, you may need to talk to him to find out what is wrong. Be sure to gather available information before the talk, talk in a private place, be a good listener, base the discussion on facts, and follow up.

15-42. It is easy to see how these factors are important. Since the purpose of talking to a worker is to get his story, the necessity of letting him do most of the talking is obvious. When he tells his story, it may help for you to restate his problem just to be sure you understand the situation. This is very often an effective way to help the person clarify the problem in his own mind. You may also ask for clarification on some points which may cause the person to change the description of the problem. The process of restating the problem will sometimes suggest a solution. At least he feels better when he "gets it off his chest." By listening, the supervisor has gathered valuable facts and, in addition, may put the complaining worker in a better frame of mind.

15-43. The nature of the complaint will suggest whether it must be investigated further, whether you can handle it yourself, or whether it must be referred to someone else. We often find that many of the dissatisfactions of workers are relatively small problems with solutions that are not too difficult. But even little problems will grow into greater problems if they are mishandled or ignored. A dissatisfied or disgruntled worker finds fault with many things. Also, he may stir up trouble among other workers.

15-44. This points out the necessity of trying to stop trouble in its early stages. This sometimes is difficult to do unless you are very alert and have actually studied the individual differences in your workers. Also, you must maintain a good relationship with each worker to be sure that he is not afraid to discuss his problems with you. If a supervisor has earned the workers' confidence, they will come to him with problems. This is a true test of the confidence that they place in him. There are many cases on record where a worker has trouble off the job that he either consciously or unconsciously transfers to the job. Sometimes the supervisor's first indication of difficulty is when the worker makes a complaint. In such cases, it is rather apparent that the supervisor may not have gained the confidence of his workers.

16. Supervising Shop Personnel

16-1. As a worker in the airframe repair shop, you use tools, machines, and equipment to repair, fabricate, and install sheet metal components. The results of your work are immediate and tangible; and at the end of a given period, you can look at and measure the products that you have turned out.

16-2. As a supervisor, you will find it a different story. Your work output will be measured in terms of what your workers do rather than in terms of what you do. You must get your work done through others. This puts you in the position of being responsible not only for what you do individually but also for what your workers do. In this section we are going to discuss some of the ways to get production out of the workers. Let's begin with what a supervisor should do with a man who has just been assigned to the shop.

16-3. **Orienting New Personnel.** When a new man is assigned to the shop (or any organization), he should be introduced to the job and the people with whom he will be working. This introduction is called an *orientation*. It is one of the most important responsibilities of the supervisor, because this is when the new worker gets his first impression of the new assignment. The impression may be good or it may be bad, depending upon how well the supervisor conducts the orientation. The effects of a bad orientation will take a long time to correct, whereas a good orientation will satisfy the four basic needs of people which we discussed earlier in this chapter: recognition, opportunity, security, and a feeling of belonging.

16-4. *Personalizing the orientation*. When a new worker reports for duty, remember that the orientation can be a distinct motivating factors, because it can convince him that he has found a good job in an interesting and important place to work. Before you begin the actual orientation, introduce yourself and then guide the conversation along personal lines something like the following:

a. Get his name correctly; then remember and use it as you proceed with the interview.

b. Find out his marital status; then (if applicable) the number, age, and sex of his children.

c. Inquire about his age.

d. Ask about his education and experience and his special training and talents.

e. Check out his hobbies and interests.

f. Find out about his home background. (You may have mutual interests—or someone already working in the shop may be from the same locality.)

g. Find out where he is living. If he is living off base, offer to help him find a car pool or satisfactory transportation to work.

h. For each bit of information you get from him, try to give him a little in return, not only about yourself but also about the men with whom he is going to work.

16-5. *Presenting "official" facts during the orientation*. After you have obtained personal information, you will know better how to orient the new worker. Among the "official" facts about which you must tell him (after requesting that he ask questions when he wants further clarification) are the following:

a. Tell him about the functions and organizational structure of your shop.

b. Let him know where his position fits into the organizational structure and the importance of his position.

c. Show him the supervisory chain of command and the person to whom he is directly responsible.

d. Inform him of the duties and responsibilities for his position and the opportunities for advancement.

e. Make sure he understands the concepts of career development and its relationship to the career program.

f. Go over with him the duties (from the specialty description and specialty training standard) that he will learn to perform in this assignment.

g. Make clear to him the standard of work required of him.

h. List for him the specific shop procedures and policies (duty hours, special details, special meetings to be attended, etc.) which he must observe.

16-6. Finally, introduce him to the other shop personnel. As you walk around, point out items of interest—particularly those that will specifically relate to his first job. It is best not to burden him with a lot of small details that he will not understand or even remember. Instead, leave these small details for him to learn when he actually starts performing the tasks. During the walk, introduce him, not as a new man, but as a person of interest by finding something to say about his qualifications or interests. Take special pains to introduce him to men who may come from the same part of the country or may know the same people. Introduce him and turn him over to the person who will be directly responsible for his training.

16-7. During the following days and weeks, as he trains on the job and works the exercises of his career development course, be sure to give him any assistance needed, let him know how he is getting along, give him credit when it is due, and gain his confidence. Learn all you can about his emotional stability and reactions, so that you can quickly solve or bypass any problems that might have a bad effect on his work. Above all, do not forget what you have learned about the basic needs of people, individual differences of people, techniques of good human relations, and problem-solving methods.

16-8. **Directing Work.** Directing work is the vital activity which must exist between preparation and actual operation. It consists of issuing instructions or otherwise indicating to subordinates what to do and how and when to do it. Desired performance depends upon mutual understanding and is frequently difficult to achieve, because the directions may have one meaning to the supervisor and another to the worker. The next 13 paragraphs—from the two-way process to the director's attitude—should help you direct work more satisfactorily.

16-9. *Two-way process*. When giving work directions, you should know your subordinates' capabilities and their workloads. Equipment, material, or suppllies needed to accomplish the work directions should also be considered. Much time may be lost, and workers may become disgruntled when a supervisor fails to consider workload or facilities at the time he gives the directions. You can probably recall many examples of poorly planned orders. In each case it is evident that the supervisor must insure that his workers understand the directions if they are to do the job satisfactorily. When you give an order, you need to know whether it has been understood. If the worker does not understand, or if he has any questions, he should let you know. This interchange of thought and information should lead to a better understanding and appreciation of the situation involved, for you as well as for the worker. Thus, we see that good directing work is a two-way process, resulting in improved performance and harmonious relations. In the absence of this two-way process, confusions and irritation develop.

16-10. It is the responsibility of the person giving the directions to make sure that they are clearly understood. A good technique to help you make sure the directions you give are understood is to ask the worker to repeat your instructions by telling you what he's going to do. Also, be sure to ask the worker whether or not he has any questions.

16-11. Through the use of the two-way process in directing, we insure that the worker knows and understands. We eliminate confusion and lost man-hours and direct the worker's efforts toward the objectives to be accomplished. Through good directing we are able to get maximum performance out of our workers.

16-12. *Giving good directions.* Now that we understand that directing is a two-way process, let's look into the characteristics of giving good work directions. The framework for a large number of our directions is provided by directives that control, such as regulations, manuals, and operating instructions. These controlling directives should be used as guides when you prepare work directions for workers. However, there are situations that call for decisions and directions that are not covered by any directives you already have. In these cases you must issue your own directives, using your organizational objectives and good judgment as guides.

16-13. Of course, directions to workers will vary in different situations and with different workers. It may sometimes be necessary to demand immediate action; whereas, in another situation, a mere suggestion of what is to be done will be satisfactory. For example, if you are giving directions to a newly assigned person, you would most likely use the request type of direction. Later you might decide to alter the type of direction you give that same person, according to his reaction. You may find that the demand or direct type of direction is necessary to motivate this particular person to action; on the other hand, it may be necessary only to suggest what you want done to achieve the best performance from him.

16-14. With experienced workers who have willing, cooperative attitudes, you would probably get the desired results with a suggested or implied direction or by asking for a volunteer. With experienced workers, the demand type of direction will often cause worker resentment, tense relations, and worker dissatisfaction if used unnecessarily, whereas a suggestion would have accomplished the desired results.

16-15. *Oral and written directives.* Worker reaction is determined to a great extent by the manner in which your directions are given. Directions may be expressed orally or in writing. Each method has its advantages. For example, it is foolish to give short, simple directions in writing or to give long, complicated directions orally.

16-16. It may sometimes be desirable to give an oral direction to supplement a written direction. This may be necessary when you wish to stimulate interest by explaining why or when you wish to afford an opportunity for questions. When issuing a new operating instruction, rule, or directive to your workers, it is sometimes wise to supplement these with oral explanations so that you can be sure the new directive is fully understood.

16-17. When issuing directions, you can check on the adequacy and eliminate possible confusion or misunderstanding by using the management tools of "What? Why? When? Where? Who? How?" if all of these questions are answered in the directions you give, the possibility of misunderstanding is vastly reduced.

16-18. Sometimes even when all of these questions are answered, the directions are still not fully effective. For example, oral directions may not be understood because you assume that the worker has a full knowledge of the subject, you use words that are too technical or too complex, you are not specific, or you include too much information.

16-19. Likewise, a written direction can be misunderstood. For example, it may contain answers to the six questions and still be too lengthy, too complicated, or arranged in an illogical sequence; make work appear unduly complicated; or lack needed authority. Therefore, we must be certain that all of the needed information is included; also we must check the language and feasibility of our directions.

16-20. *Attitude of the director.* Now that we have discussed how to insure that our directions are complete, let's consider the attitude of the individual who gives the directions. Perhaps you have seen a supervisor give an order in words but suggest by his attitude that the order is unimportant. For example: "The chief wants us to count all those parts in the bench stock again. Take care of it as quickly as you can so that we can get at something worthwhile. Here's a copy of the count we made last week if you want it!"

16-21. It is not hard to picture the attitude of the workers assigned to this job. If their supervisor thinks that it is a waste of time, it stands to reason that the workers will lose interest in their jobs and perform the work in a careless manner. We must believe in the importance of the work we are doing if we are going to do it well and enjoy doing it. We must also feel that the directions we give are important if we expect our workers to do their jobs well and enjoy doing them. Sometimes we must assume that the chief knows more than we do, perhaps even more than he can tell us.

16-22. **Rotation of Duty Assignments.** The supervisor who assigns men to assist in paperwork duties will be fulfilling some of the supervisory and management requirements for 5-level trainees, and at the same time, will be training assistants who can help free him from spending so much time in the office. This will give him more opportunity to supervise fabrication and repair jobs. Whether or not he assigns subordinates to assist with paperwork will usually be influenced by the number of men who are training on the job for the 5 skill level. For example, think of ourself. You are now studying the supervision and management portion of CDC 53450. It is important that the work assignments you make to others parallel (as much as possible) the material you are studying. However, if no one in the shop is on 5-level OJT, the supervisor or foremen should rotate all workers so that each can learn to assist with the paperwork.

16-23. The other duty rotation that may occur in the average airframe repair shop is truck driving. You will find it helpful to have each airframe repairman qualified as a vehicle operator; then set up a rotation roster for the duty. Some supervisors find that a weekly rotation cycle is a workable practice. Thus, one man, for a week at a time, will be responsible for obtaining a truck from the motor pool, using it for jobs and errands during the day and returning it to the pool at the end of the day. Another rotation plan used by some supervisors is to assign the team chief (who may have more than one team) to drive the truck. This plan will allow the team chief to go freely from one job site to another and run the errands necessary for each team.

16-24. Other than these exceptions (paperwork and truck driving), most of the duty assignments in the shop are controlled by work orders, and each team will probably perform a complete job. Usually, the same crew will stay with a job from patternmaking through installation. Thus each man performs a variety of assignments and is not confined to a single operation.

16-25. **Performance Requirements.** Just as you feel that you have a right to know exactly what your supervisor expects from you, so do your workers have that right. You also believe you should be told how your work will be judged. Those whom you supervise are no different; they, too, want to know what their job is and how you will go about judging their performance. Both you and your subordinates are seeking performance requirements. Each task is followed by the requirements which have been determined to be acceptable for the task. Also, the performance requirements fulfill a function not done by the specialty training standard—*quantity of results in a given time, quality of results in terms of how well the job must be performed, and manner of performance.* Actually, a performance requirement is just a fancy term for a description of what constitutes a job satisfactorily done.

16-26. *Determining performance requirements.* The approach to determining performance requirements should be realistic and practical. Frequently, we have difficulty in setting requirements because we overemphasize operating details of the job rather than the results which the job must achieve so that the mission of our unit will be accomplished. By setting the requirements at a reasonable level, we stimulate people to work. These individuals are neither overloaded nor underloaded. We put within their reach, through a safe workload, the satisfaction of a job well done. From your own experience you have probably seen what happens when workers are overloaded. Some of these results are accidents, errors, fatigue, resentment, and slowdown. Conversely, the situation is also bad when workers do not have enough to do. The results here are usually mischief, excessive cost of operations, and grievances. These factors of overload and underload of workers are important when determining the level of performance requirements. This helps us to determine whether we get the results that we expect.

16-27. Performance requirements for each work operation must describe acceptable performance. They should be set at a level of performance which can be fairly expected of any qualified, competent worker who may be assigned to that position. It is generally true that workers will become frustrated and quit trying to reach a goal if it is set too high. The requirement must be a level attainable by average workers. Also, there should be room for the exceptional workers to perform above the requirement.

16-28. In this respect, you can readily see the dangers of setting a requirement based only upon the level attained by the worker now assigned to the position. This assumes that the worker is meeting all the requirements of the position in exactly an acceptable manner. If the position is filled by a person of unusually high qualification, it penalizes the worker by rating his outstanding performance as only satisfactory. In the same situation it would penalize future workers who were competent but not outstanding by rating their performance as unsatisfactory or unacceptable. Again, if the worker's performance is actually inadequate but is used as the basis for writing performance requirements, the level of satisfactory performance will be too low.

16-29. Another factor which you must take into consideration when writing performance requirements is the fact that all workers do not produce the same amount and quality of work. Rather, there is a certain range of performance which is considered acceptable. Performance below this level would be considered below average and possibly unacceptable. Performance exceeding this level would be considered above average and possibly outstanding. This range should also be realistic.

16-30. Each supervisor must make certain that the worker understands fully what is expected in his job. The following procedures can be used for determining performance requirements:

a. Select the task or major work factors of the job.

b. Decide tentatively what is reasonable to expect as to:

(1) Quantity of results in a given time.
(2) Quality of results in terms of how well the job must be performed.
(3) Manner of performance.

c. Discuss the tentative requirements with:

(1) Workers assigned to the job.
(2) Your supervisors.
(3) Other supervisors determining requirements for the same type of operation.

d. Check for possible effect of existing requirements:

(1) Trade or craft requirements.
(2) Management data.
(3) Requirements of higher echelons.

e. Review and formulate firm requirements to reach full understanding by workers affected.

16-31. *Using performance requirements.* Just as with all the other tools of management, simply developing a set of performance requirements and placing them in a neat file is almost the same as doing nothing. They must be used to be of any benefit. The supervisor must weigh the worker's performance continually against the requirement and discuss it with him periodically. He must then take action consistent with the worker's performance by giving recognition to workers exceeding requirements, helping workers who are below requirements by training or other appropriate means, and motivating workers who are doing acceptable work to get them to perform better, if they are capable.

16-32. There are a number of distinct benefits that the supervisor can realize from proper development and use of performance requirements. For one, it can aid in production by establishing minimum acceptable production goals for each worker. For another, you will benefit because of a better attitude on the part of your workers toward the work situation and because better job satisfaction will be created, since the workers will know what and how much is expected of them. Other advantages the supervisor can expect from the use of performance requirements are these: they create a sound basis for estimating future work capacity; they provide data for planning, organizing, and assigning work; they provide a basis for determining who needs additional training and how much is needed; and they provide a sound basis for personnel actions and formal ratings.

MODIFICATIONS

Chapter 4 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

602

2-3

53450 05 25

WORKBOOK

SUPERVISION AND TRAINING

SELF-TEACHING AIDS
CRE
VRE
SRG

This workbook places the materials you need *where* you need them while you are studying. In it, you will find the Chapter Review Exercises and their answers, and the Volume Review Exercise. You can easily compare textual references with chapter exercise items without flipping pages back and forth in your text. You will not misplace any one of these essential study materials. You will have a single reference pamphlet in the proper sequence for learning.

These devices in your workbook are autoinstructional aids. They take the place of the teacher who would be directing your progress if you were in a classroom. The workbook puts these self-teachers into one booklet. If you will follow the study plan given in "Your Key to Career Development," which is in your course packet, you will be leading yourself by easily learned steps to mastery of your text.

If you have any questions which you cannot answer by referring to "Your Key to Career Development" or your course material, use ECI Form 17, Student Request for Assistance," identify yourself and your inquiry fully and send it to ECI.

Keep the rest of this workbook in your files. Do not return any other part of it to ECI.

EXTENSION COURSE INSTITUTE
Air University

TABLE OF CONTENTS

Study Reference Guide

Chapter Review Exercises

Answers For Chapter Review Exercises

Volume Review Exercise

ECI Form No. 17

STUDY REFERENCE GUIDE

1. *Use this Guide as a Study Aid.* It emphasizes all important study areas of this volume.

2. *Use the Guide as you complete the Volume Review Exercise and for Review after Feedback on the Results.* After each item number on your VRE is a three digit number in parenthesis. That number corresponds to the Guide Number in this Study Reference Guide which shows you where the answer to that VRE item can be found in the text. When answering the items in your VRE, refer to the areas in the text indicated by these Guide Numbers. The VRE results will be sent to you on a postcard which will list the *actual VRE items you missed.* Go to your VRE booklet and locate the Guide Number for each item missed. List these Guide Numbers. Then go back to your textbook and carefully review the areas covered by these Guide Numbers. Review the entire VRE again before you take the closed-book Course Examination.

3. *Use the Guide for Follow-up after you complete the Course Examination.* The CE results will be sent to you on a postcard, which will indicate "Satisfactory" or "Unsatisfactory" completion. The card will list *Guide Numbers* relating to the questions missed. Locate the numbers in the Guide and draw a line under the Guide Number, topic, and reference. Review these areas to insure your mastery of the course.

Guide Number

Guide Numbers 500 through 519

500 Introduction to Inspections and Evaluations; Factors in the Inspection of Fabricated and Repaired Items; pages 1–4

501 Inspections and Evaluations Insuring Safe Airframe Repair Shop Operation; pages 4–5

502 Inspection of Equipment; Inspection of Personnel; pages 5–9

503 Inspection of Supplies; Interpretation and Correction of Inspection Findings; pages 9–11

504 Introduction to Optical Alignment; Fundamentals of Optics; pages 12–16

505 Telescopes; Principles of Operation of the Telescope; Sight Levels; pages 16–19

Guide Number

506 The Transit; pages 19–26

507 Auto-Reflection Equipment: General; Principles; Auto-Reflection Angle Mirror; Accuracy and Sensitivity of Auto-Reflection; Tolerances in Auto-Reflection Readings; pages 26–30

508 Auto-Reflection Equipment: Sequences of Setup of Auto-Reflection Mirror; pages 30–35

509 Tilting Dumpy Level; pages 35–37

510 Optical Micrometer; pages 37–43

511 Introduction to Personnel Management; Promoting Harmonious Relationships and Resolving Personnel Problems: General Personality Traits of a Leader; Basic Needs of People; Individual Differences; pages 44–47

Guide Number

512 Promoting Harmonious Relationships and Resolving Personnel Problems: Techniques of Good Human Relations; Problem Solving; Resolving Personal Problems; pages 47–50

513 Supervising Shop Personnel: General; Orienting New Personnel; Directing Work; Rotation of Duty Assignments; pages 50–53

514 Supervising Shop Personnel: Performance Requirements; pages 53–54

515 Introduction to Training; The Role of On-The-Job Training; pages 55–57

Guide Number

516 Duties and Responsibilities for OJT; pages 57–62

517 Conducting On-The-Job Training: General: Training Principles; Training Methods; Training Techniques; Task Breakdowns; pages 62–66

518 Conducting On-The-Job Training: Using the CDC; pages 66–67

519 Conducting On-The-Job Training: Determining Training Needs; Making Work Assignments; Determining Effectiveness of the OJT Program; pages 67–69

CHAPTER REVIEW EXERCISES

The following exercises are study aids. Write your answers in pencil in the space provided after each exercise. Immediately after completing each set of exercises, check your responses against the answers for that set. Do not submit your answers to ECI for grading.

CHAPTER 1

Objectives: To demonstrate a knowledge of the factors necessary to perform inspections of completed repairs, safe shop operation, personnel, and supplies; and to show the ability to interpret and correct discrepancies noted during inspection.

1. What is the purpose of the hand mirror, and how is it used during inspections of fabricated parts and repairs? (1-2)

2. How does an inspector check completed repairs? (1-2)

3. Name several of the factors required to maintain original strength in a structure during a repair. (1-4–13)

4. Although not specified in blueprints or specifications, what one factor should you consider as a basic reason for rejection of a fabricated or repaired part during your inspection? (1-23)

5. If not corrected, what shop discrepancy could cause personnel in the shop to trip and fall? (2-7)

Situation: There is rust on the unpainted surface of a machine. NOTE: *It has already been determined that moisture is not the cause. Further checks have also revealed that machines on the opposite side of the shop do not have rust on the unpainted surfaces.*

6. What is the probable cause? (2-9)

Situation: Suppose that a shop inspection reveals that different types of scrap metal are mixed in the same containers.

7. What should you do to correct this discrepancy before the metals are sent to redistribution and marketing? (2-11)

Situation: On the fifth day of June you are inspecting the fire extinguishers in the shop and find that they were checked on the second day of June. However, the seal is broken on one, indicating that the extinguisher has been used.

8. What should you do? (2-12)

9. Are the wheel guards that are illustrated in figure 5 acceptable from the standpoint of safety? Why? (3-6; Fig. 5)

10. Why, during your inspection of shop personnel, should you be especially watchful for the shop practical joker? (4-2)

11. What is included in the personal inspection of a worker who is operating a bench grinder, such as that shown in figure 5? (3-6; 4-3; Fig. 5)

12. Why is the wearing of rings, bracelets, or loose clothing potentially dangerous to the wearer while operating shop machinery? (4-3)

13. During an inspection of supplies, how can you tell which item is in the wrong location if ¼-inch rivets are mixed with 1/8-inch rivets? (5-4, 5)

14. If during inspection of the shop, you have found oily and clean rags mixed in the rag containers, what can you do to correct this discrepancy? (The containers *are* properly marked.) (6-4)

15. What corrective action should you recommend to the base supply bench stock section if an inspection of bench stock reveals that several items are stored in the wrong location, even though the stock numbers and item descriptions are correct? (5-5; 6-10)

16. During your inspection of your material storage area within your shop, you find bench stock and work order materials (that should be kept separately) have been mixed. What are three things you must determine to correct this discrepancy? (6-11)

CHAPTER 2

Objectives: To demonstrate a knowledge of fundamentals of optics as related to optical equipment used in alignment of aircraft structures; and to show the ability to evaluate and make proper decisions relative to the physical features and operating principles of optical equipment and their correct erection procedures.

1. Name three of the various happenings that could cause misalignment of an aircraft. (Intro.)

2. What is the difference between a *translucent* medium and an *opaque* medium? (7-3)

3. What is the difference between *reflected* and *refracted* light rays? (7-4)

4. What effect does water, glass, or some other transparent medium have on light traveling from these media back into the air? (7-10)

5. Describe a *lens.* (7-16)

6. Adjustment of the focusing lens of the telescope is made for what purpose? (8-4)

7. Name the two types of telescopes and the difference of the projected image as seen through each of them. (8-8, 9)

8. What three things are required for a good optical system? (9-8)

9. Of what parts does a *sight level* consist? (10-1)

10. What basic optical instrument is common to both the sight level and the transit? (10-1; 11-3)

11. Name the functional parts common to transits and sight levels. (11-5)

12. What are the locations of the plate leveling and the precision leveling vials on the transit? (11-13)

13. What are three geometrical requirements that must be built into a transit and maintained to obtain accurate results with that transit? (11-14)

14. When you position the tripod and baseplate during setup of a transit, what is the minimum focal distance that must be maintained from the closest reference point? (11-17)

15. What is the first thing that you must do after precision-leveling the transit to check the geometry of the transit? (11-25, 26)

16. What is *auto-reflection?* (12-2)

17. In auto-reflection, to what distance must the telescope be focused in relation to the target and mirror? Why is this distance necessary? (12-8)

18. Auto-reflection mirrors are front-surfaced mirrors. Why are they coated on the front surface? What is the front surface coated with? (12-9)

19. What material is preferred when cleaning an auto-reflection mirror? (12-13)

20. In auto-reflection, if the mirror is tilted 5° from the perpendicular, what will be the degree of separation between the incident ray and the reflected ray at the telescope? (12-16)

21. During buck-in of the auto-reflection mirror, what are the prime duties of the two persons necessary to perform this operation? (12-30; Note)

22. What is the purpose of the eyepiece focusing ring on the telescope used on the tilting dumpy level? (13-6)

23. Describe *optical micrometers* and explain how they are used. (14-1–3)

24. When installing the tilting dumpy level on the threaded head of the tripod, explain exactly when you are aware that the threads are properly meshed. (14-8)

25. If, during the setup and adjustment of the tilting dumpy level and after rough-leveling the instrument, you find that the height adjustment is incorrect, what must you do to the optical micrometer and the level to remedy the situation? (14-11)

26. How is the optical micrometer used to adjust the crosshairs into coincidence? (14-13)

CHAPTER 3

Objectives: Given personnel management and supervisory situations, to list personality traits of leaders and solve problems concerning human needs and techniques of good human relations; to demonstrate a knowledge of supervisory capability; to determine proper orientation in sequence for new workers; and answer questions about personnel evaluation.

1. What are five personality traits which you have observed in supervisors that can be added to the text list? (15-1; 2)

2. What are the ten personality traits of a leader that are listed in this text? (15-2)

Situation: Airman Ward has completed his 5-level OJT in the airframe repair shop. He is a conscientious worker and has a great deal of pride in his work. He can do a good job of teaching new trainees how to operate the shop machines and how to use tools properly. The supervisor has often assigned him these duties. However, the supervisor has usually picked Airman Baker, instead, to be a team leader and to assist with shop paperwork. The supervisor has also frequently congratulated Baker on how well he worked with men and did his job. At the same time, the supervisor has a dislike for training and has seldom congratulated Ward. Finally, after several months, Airman Ward has become disinterested and the quality of his work has deteriorated.

3. What basic human need has the supervisor been overlooking that has caused Airman Ward to lose interest? (15-4)

Situation: There are several workers available for dispatch from your shop to assist in removing a heavy aircraft part to be repaired in your shop. The airmen available are of equal skill and experience.

4. Which of the differences between individuals discussed in the text should you consider prior to selecting a worker to perform this job? (15-11–14)

Situation: Airman Cain has done a good job in the airframe repair shop, but he is a shy boy. He has, for example, only a "Good Morning" or a nod for his supervisor. However, since Airman Cain has been doing his job well, his supervisor has left him alone and never told him how he is getting along. But now, after several months, Airman Cain has become restless and is frequently absent. His attendance record has become poor for seemingly minor reasons, and his production has fallen off. His supervisor talked to him about his absences.

5. In the foregoing situation, what was apparently wrong? (15-17)

Situation: Airman Day frequently gets injured while on the job and in the airframe repair shop. As a supervisor, you must decide what to do to solve the problem. Answer the following questions concerning the handling of Airman Day's problem:

6. *a.* Which step in problem-solving techniques will help you to define Airman Day's problem? (15-26, 27)

   b. Which of the steps in problem-solving techniques did you use to find out that Airman Day had a history of continuous accidents before entering the Air Force? (15-28)

   c. Which step would you be using if Airman Day were assigned additional training in safe operation of machines? (15-32)

7. When discussing a problem with a complaining worker, what is one of the most important things a supervisor can do to get the facts and, at the same time, reduce the dissatisfaction of the worker? (15-41, 42)

8. Correctly sequence the actions listed below in the order in which you should perform them when orienting a newly assigned worker:

   a. Discuss the shop and his new job.
   b. Introduce him to other personnel.
   c. Discuss personal topics, such as his experience and his family.
   d. Turn him over to the person who will be directly responsible for his training.
   (16-4–6)

9. What type of direction is inferred in each of the four examples listed below?

   a. "George, would you repair that hole with a flat seam patch?"

   b. "It would be helpful to remove the canopy before we repair it."

   c. "John, make a replacement for this hot air line and install it immediately."

   d. "It is necessary that we complete this job today. Who is willing to work late to get the job finished on time?"

   (16-13, 14)

10. How can the airframe repair shop supervisor free himself from some of the paperwork duties of the shop office? (16-22)

613

MODIFICATIONS

Pages 10 - 12 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

ANSWERS FOR CHAPTER REVIEW EXERCISES

CHAPTER 1

1. To examine inaccessible areas. It is used in much the same way a dentist examines the back side of a person's teeth.

2. He checks by sight, feel, and measurements.

3. Use of the recommended gage and composition of materials; the proper size, type, and installation of fasteners; heat treatment of materials when necessary; and proper cutout radius and edge distance.

4. Poor quality or sloppy workmanship.

5. Scrap metal on the floors.

6. The probable cause is acid fumes from an acid storage area located near the machines. Such fumes would most likely cause the unpainted surfaces to rust if they came into contact with them.

7. You should separate the different types of metal, placing each in a clearly marked container.

8. You should send it to the fire extinguisher shop for an inspection or for recharging.

9. Yes, the wheel guards are acceptable, because they cover two-thirds of each grinding wheel.

10. Because of his pranks, he will eventually injure himself or someone else, or both.

11. Be sure that the operator is wearing eye goggles or a faceshield.

12. Such items might get caught by the machine, causing the hand or arm to be pulled into the machinery or cutting blades.

13. Check the item description against the stock number and bin location number.

14. Caution your workers on separation of clean and oily rags, and closely observe the containers to determine the offender.

15. You should recommend that the location number of the items be checked and the numbers corrected as necessary.

16. (1) Determine whether or not there is proper storage area space; (2) determine if the materials have been properly marked; and (3) determine if your personnel are properly trained in storing of the materials.

CHAPTER 2

1. Any of the following items could cause misalignment of an aircraft: hard landings, overload conditions, turbulence in flight, excessive speeds, acrobatic flying, replacement of components, or repairs to major structural units.

615

2. Light will pass through a *translucent* medium but will not pass through an *opaque* medium.
3. *Reflected* light rays are those that, when they strike a new medium, are sent back into the medium from which they came. *Refracted* light rays pass into a new medium and are forced to change course direction.
4. Light is slowed down and bent or refracted as it travels back into the air from these media.
5. A *lens* is a piece of transparent refracting substance (usually glass) whose opposite surfaces may be both curved or one surface of which may be curved while the opposite surface is flat.
6. To bring the rays into focus by forming an image of the object being sighted on the plane of the crosshairs.
7. The two types of telescope are the *celestial* and the *terrestrial.* The celestial is generally used by astronomers and leaves an inverted image. A terrestrial (land) telescope erects the image of an object.
8. Three things required for a good optical system are (1) proper magnification, (2) ultimate resolution, and (3) clear definition.
9. A sight level consists of a telescope which can be set up so that its optical axis will rotate in a horizontal plane about the vertical axis when the instrument is level.
10. The telescope is common to both the transit and the sight level.
11. Eyepiece focusing ring, objective focusing knob, and the leveling screws.
12. One plate leveling vial is located on the upper plate of the instrument and the other is mounted on one of the standards. The precision leveling vial is mounted directly onto the telescope.
13. (1) The horizontal axis and vertical axis must be perpendicular to each other; (2) the optical axis of the telescope must pass through the vertical axis of the instrument; and (3) the optical axis must be perpendicular to the horizontal axis.
14. 6 feet between the closest predetermined reference point and the tripod.
15. Establish a third reference point that requires transiting the telescope through an arc equal to or greater than necessary to locate the required points involved.
16. *Auto-reflection* is the act of looking through a telescope at a mirror and viewing an image of a target that is attached to the telescope.
17. The telescope must be focused at *twice* the distance between the target and the mirror. The image reflection from a flat mirror appears to be a distance behind the mirror equal to the distance that the target is in front of the mirror.
18. Auto-reflection mirrors are coated on the front side to eliminate multiple images. They are coated with either aluminum or chromium.
19. An approved cleaning fluid and optical cleaning paper.
20. The separation will be 10° at the telescope.

21. During buck-in one person observes coincidence of the vertical line and vertical crosshair through the transit, while the other operator makes adjustments of the auto-reflection mirror by use of the lateral adjuster.

22. To compensate for variations in the eyesight of different observers.

23. *Optical micrometers* are attachments for levels and transits, and they are used to displace the line of sight. They have a disc of optical glass with flat parallel faces and are mounted on the instrument so that the plate is in front of the objective lens.

24. You are aware that the threads are properly meshed when you rotate the threaded base of the instrument counterclockwise and hear a click, indicating that the threads meshing has occurred.

25. You must remove the optical micrometer and level from the tripod and return them to their case, because you must make no adjustments to the tripod while the instrument is installed.

26. The optical micrometer dial knob is used to rotate the optical flat to bring the crosshairs to coincidence with the nearest 1/8-inch scale graduation.

CHAPTER 3

1. Your list of five additional traits may include, or be similar to, those listed below. (Any five are acceptable provided that each describes qualities or patterns of behavior which will help a person be a leader.)

   Neat appearance
   Cooperativeness
   Courageousness
   Creativity
   Flexibility
   Good humor
   Power of observation
   Ability to profit by experience
   Resourcefulness
   Sound judgment
   Thoroughness
   Truthfulness
   Versatility.

2. Ten personality traits from the text:

   Friendliness
   Initiative
   Ability to make decisions
   Interest in people
   Understanding
   Sincerity
   Pride in accomplishment
   Patience and emotional control
   Fairness
   Personality.

3. The supervisor has been overlooking Airman Ward's need of recognition for the good work he has been doing with the trainees.

4. The *physical* capability of the worker.

5. Airman Cain probably lost interest in his job because he was shy and needed more encouragement than others might need; from the beginning he never knew what the supervisor thought of his work. A supervisor should let each worker know how he is getting along.

6. *a.* The establishing of objectives.
   b. The gathering of facts.
   c. The taking of action.

7. He can be a good listener and let the complaining worker do most of the talking.

8. *c.* Discuss personal topics, such as his experience and his family.
   a. Discuss the shop and his new job.
   b. Introduce him to other personnel.
   d. Turn him over to the person who will be directly responsible for his training.

9. *a.* Request type of instructions.
   b. Suggested or implied directions.
   c. Demand or direct type of directions.
   d. Request for volunteers.

10. By assigning the workers, on a rotational basis, to assist with the paperwork.

MODIFICATIONS

Pages 17-18 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

STOP– **1. MATCH ANSWER SHEET TO THIS EXERCISE NUMBER.** **2. USE NUMBER 1 PENCIL.**

53450 05 25

VOLUME REVIEW EXERCISE

Carefully read the following:

DO'S:

1. Check the "course," "volume," and "form" numbers from the answer sheet address tab against the "VRE answer sheet identification number" in the righthand column of the shipping list. If numbers do not match, take action to return the answer sheet and the shipping list to ECI immediately with a note of explanation.
2. Note that numerical sequence on answer sheet alternates across from column to column.
3. Use only medium sharp #1 black lead pencil for marking answer sheet.
4. Circle the correct answer in this test booklet. After you are sure of your answers, transfer them to the answer sheet. If you *have* to change an answer on the answer sheet, be sure that the erasure is complete. Use a clean eraser. But try to avoid any erasure on the answer sheet if at all possible.
5. Take action to return entire answer sheet to ECI.
6. Keep Volume Review Exercise booklet for review and reference.
7. If *mandatorily* enrolled student, process questions or comments through your unit trainer or OJT supervisor.
   If *voluntarily* enrolled student, send questions or comments to ECI on ECI Form 17.

DON'TS:

1. Don't use answer sheets other than one furnished specifically for each review exercise.
2. Don't mark on the answer sheet except to fill in marking blocks. Double marks or excessive markings which overflow marking blocks will register as errors.
3. Don't fold, spindle, staple, tape, or mutilate the answer sheet.
4. Don't use ink or any marking other than with a #1 black lead pencil.

NOTE: The 3-digit number in parenthesis immediately following each item number in this Volume Review Exercise represents a Guide Number in the Study Reference Guide which in turn indicates the area of the text where the answer to that item can be found. For proper use of these Guide Numbers in assisting you with your Volume Review Exercise, read carefully the instructions in the heading of the Study Reference Guide.

Multiple Choice

Chapter 1

1. (500) The purpose of using a feeler gage when inspecting fabricated and repaired items is to check for

   a. corrosion.
   b. the proper width of the rivet shop head.
   c. the proper height of the rivet shop head.
   d. loose rivets.

2. (500) The main reason why replacement materials used in repairs should have the same gage and composition as the original materials used is that

   a. corrosion may be prevented.
   b. weight limits may be maintained.
   c. the original strength may be restored.
   d. compliance with Air Force policy may be attained.

3. (500) Who has the authority to change incorrect specifications on a blueprint?

   a. The repairman.
   b. The commander.
   c. The maintenance supervisor.
   d. The originator.

4. (501) What disposal should be made of scrap metal?

   a. Scrap metal should be burned in disposal pits.
   b. Scrap metal should be disposed of by burning.
   c. Scrap metal should be placed in a separate storage area.
   d. Scrap metal should be placed in refuse barrels for removal to the garbage areas.

5. (502) Which of the following is included in the cleanliness inspection for the rolls of the slip roll forming machine?

   a. Pits or creases in the rolls.
   b. Ivory painted rolls.
   c. Orange painted rolls.
   d. Red painted rolls.

6. (502) Which of the following should be a definite observation check when workmen are operating power slip roll forming machines?

   a. That gloves *are* worn.
   b. That loose clothing *is not* worn.
   c. That an eye protection *is* worn.
   d. That not less than *three* workmen are operating the machine.

7. (503) What action should you take if an inspection reveals a grinding wheel that is cracked from the face to the arbor hole on one side of the wheel and halfway on the opposite side?

   a. Warn the workmen to make certain a face shield is used when operating that grinder.
   b. Warn the workmen to use the wheel only for small jobs.
   c. Leave the wheel on the machine, but warn the workmen against using the cracked wheel.
   d. Replace the grinding wheel.

8. (503) During a safety inspection by a ground safety inspector, oily rags are found mixed with clean rags. Your personal inspection isolates the deficiency to the neglect of a workman. What should you do after counselling the workman in the proper use of storage containers?

   a. Make followup checks to insure that proper storage containers are being used properly.
   b. Remind the workers of the incident at the next safety meeting.
   c. Forget the incident, since you have counselled workman.
   d. Counsel shop personnel for several days in the proper use of rag storage.

Chapter 2

9. (504) If a beam of light strikes a flat, polished metal surface, most of the light is

   a. refracted.
   b. reflected.
   c. diffused.
   d. absorbed.

10. (504) If a beam of light travels from air into water, the beam at the point of entry should be

    a. reflected.
    b. straight.
    c. absorbed.
    d. refracted.

11. (504) Which of the following will determine whether light rays passing through a lens will be converged or spread out?

    a. The transparency of the lens.
    b. The thickness of the lens.
    c. The shape of the lens.
    d. The angle of incidence.

12. (504) To shift the direction of light rays in optical instruments, the manufacturers utilize glass

    a. eyepieces.
    b. lenses.
    c. prisms.
    d. telescopes.

13. (504) A convex lens differs from a typical prism in that a convex lens

    a. bends light rays as they enter it.
    b. has nonparallel surfaces.
    c. focuses parallel light rays to a point.
    d. bends light rays as they leave it.

14. (505) Both the mechanical axis and the optical axis of a telescope are

a. imaginary or real straight lines.
b. centered to the left of the crosshairs.
c. lines around which the telescope rotates counterclockwise.
d. lines around which the telescope rotates clockwise.

15. (505) If the right side of an image appears to be on the left, then you should know that the telescope you are using is a

a. terrestial telescope.
b. celestial telescope.
c. magnifying telescope.
d. long-range telescope.

16. (505) Before any readings are taken with a telescope,

a. any parallax condition must be eliminated.
b. the crosshairs must appear sharp and black.
c. you must focus the eyepiece on the crosshairs.
d. the telescope must be centered vertical to the horizon.

17. (505) The resolving power of a telescope is the capacity of its lens to show

a. reflected objects.
b. parallaxis.
c. magnification.
d. detail.

18. (505) (506) An item of equipment common to both the *transit* and *slight level* is the

a. adjustable caliper.
b. telescope.
c. auto-reflection mirror.
d. quartsite leveling vials.

19. (506) Moving the eyepiece of a telescope on a transit to a higher elevation is called

a. "transit telescope."
b. "rotate telescope."
c. "reverse instrument."
d. "eliminate resolution."

20. (506) If the precision bubble does *not* center in the level vial in setting up a transit, which of the following describes the amount of an error correction which should be made through adjustment of the leveling screws?

a. One-fourth error.
b. One-half error.
c. Three-fourths error.
d. All of the error.

21. (506) To perform a transit geometry check with a transit, you should first

a. establish the first reference point.
b. establish the third reference point.
c. establish the second reference point.
d. sight the nearest alignment point.

22. (507) If auto-reflection equipment is *not* available and you must first establish a reference plane perpendicular to the line of sight, which instrument should you use?

a. A transit.
b. A sight level.
c. A telescope target.
d. A telescope plane.

23. (507) When using auto-reflection, the reading known as *zero-zero* occurs when

a. there is no tilt to the mirror.
b. there is no displacement in the target.
c. the parallax has been eliminated on the target.
d. the mirror has no tilt and there is no displacement of the target image.

24. (507) Auto-reflection angle mirrors are front coated to eliminate

a. parallax.
b. plano-parallels.
c. multiple images.
d. excessive light.

25. (507) In auto-reflection, a 5° tilt from perpendicular of the mirror will cause a separation between the incident ray and reflecting ray at the telescope of

a. 20°.
b. 15°.
c. 10°.
d. 5°.

26. (507) A reading for a given amount of tilt in the auto-reflection mirror can be calculated by using

a. a tolerance chart.
b. a trigonometric chart.
c. the hypothesis of a triangle.
d. an STA compatibility chart.

27. (509) Which of the following represents an advantage in using the tilting dumpy level?

a. The telescope is pivoted about a vertical axis which intersects the horizontal axis of the instrument.
b. The height of the telescope axle remains in a fixed position.
c. The center spindle always remains in a fixed vertical position.
d. The horizontal plane swept by the leveled line of sight is always the same distance above the ground.

28. (510) During the installation of the tilting dumpy level, the threaded portion is placed on the threaded head of the tripod. You should then rotate the threaded base of the instrument counterclockwise until a click is heard which will indicate that the

a. head is seated snugly.
b. head is tight enough for optics.
c. head is cross-threaded.
d. threads are meshed.

29. (510) An adjustment of the optical flat on the optical micrometer is made with the

a. precision level vial.
b. tilting screw drum.
c. optical micrometer dial knob.
d. split level coincidence head adjuster.

624

30. (511) Which, if any, of the basic needs of people will be satisfied in the following orientation interview? The supervisor continues to work at his desk when the new man arrives, mispronounces and fails to remember the new man's name, tells the new man what a good supervisor he is, and terminates the interview with the comment, "Go on out and meet the others."

a. Security.
b. Recognition.
c. Opportunity.
d. None of the above.

31. (511) Each of the following represents a grouping of the basic differences between people *except* for

a. a mental grouping.
b. a social grouping.
c. an ethnic grouping.
d. a physical grouping.

32. (511) In the following situations, which individual difference will cause the worker to react differently?

Example 1: Suppose the supervisor walked up to a worker in the airframe repair shop and said, "Say Frank, I see that you finally got rid of that oil cooler." The supervisor was referring to an oil cooler that had required a difficult transition repair. Frank had worked very hard and was proud of the job. He took the supervisor's comment as somewhat of a commendation.

Example 2: Now, suppose the same supervisor approached Frank in the same way and said the same same thing. However, in this case, Frank had worked for many hours and was unable to make the oil cooler work correctly. Another worker had quickly located the trouble as being an error in the pattern development Frank had produced. Frank was somewhat angry at himself for not having found the error. He was standing at the work bench pondering over the situation, when the supervisor made the above comment.

a. Ethnic.
b. Emotional.
c. Psychological.
d. Social.

33. (512) The supervisor who thinks of his people first, is willing to sit down and talk with them, and tells them of changes in advance is known as being

a. problem-centered.
b. worker-centered.
c. mission-centered.
d. production-centered.

34. (512) Which of the following is *not* included in organized problem-solving procedures?

a. Defining the problem and establishing an objective.
b. Building worker's confidence in your ability to handle people.
c. Gathering facts, weighing, and deciding.
d. Taking action.

35. (513) When does the directing work phase of supervision begin?

a. It begins after preparation and before the actual operation.
b. It begins at the end of the operation.
c. It begins when the operation is underway.
d. It begins when the operation starts.

632

36. (514) A performance requirement is, in effect, the level of performance which should be expected of the

a.	truly outstanding worker.	c.	below average worker.
b.	above average worker.	d.	average worker.

37. (514) If the performance requirements for a job are set too high, the average satisfactory worker will most likely

a. become an excellent worker by trying to attain this goal.
b. become frustrated.
c. usually attain this goal.
d. begin to set higher standards for himself.

MODIFICATIONS

Pages 26-27 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.